Determinants of Training and the Performance of New Firms

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The Faculty of Economics, Business Administration and Information Technology of the University of Zurich hereby authorizes the printing of this Doctoral Thesis, without thereby giving any opinion on the views contained therein.

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Zurich, October 2011 *Tobias Stucki*

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Thesis summary

Based on firm-level survey data, this thesis deals with two factors that are especially for Switzerland of high economic importance: (a) apprenticeship training and (b) start-ups. Apprenticeship training is in German-speaking countries a widespread practice of skill formation at the upper-secondary level. An open question, however, is whether this type of training will remain as attractive for the firms as it was in the past. Significant changes within the firm structure, such as a shift in the employment structure from low to high skills, a spreading of a body of new technologies (in particular the diffusion of "information and communications technologies", ICT), and a redesign of a firms' workplace organization, can be observed over the last years and present new challenges for the apprenticeship training system. These interrelated changes are often conceptualized as a shift towards a "new firm paradigm" (e.g., Burns and Stalker 1994, Lindbeck & Snower 2000, Milgrom & Roberts 1990). Econometric studies dealing with a firm's provision of apprenticeship training so far did not pay much attention to the influence of these changes within the firm structure. Based on data from two large sample surveys conducted among Swiss companies, the study presented in Chapter 2 attempts to fill this gap. The detailed information on the use of ICT, redesign of workplace organization and the input of human capital makes it possible to analyze the impact of the three constituent elements of the "new firm paradigm" on a firm's provision of apprenticeship training in the same model. Furthermore, to analyze complementarities, interaction terms of human capital, ICT intensity and workplace organization can be included. Estimation results show that apprenticeship training is an appropriate way of skill formation in advanced economies. In leading-edge segments of the economy where the three elements of the "new firm paradigm" play a significant role this, however, may not be the case.

The second part of this work, which comprises two studies, focuses on new firms. New firms are an important source of new business practices and new technologies, and thus seem to be important drivers toward such a "new firm paradigm". Despite expected positive impacts, relatively little is known about new firms so far. Providing evidence on the potential

effect of financial constraints on firm success is of particular interest. Financial constraints are often seen as a strong barrier to entrepreneurship, and also to firm's innovative effort. Accordingly, many studies deal with the question of how access to finance could be promoted (e.g., European Commission 2007a; OECD 2004, 2005; World Bank 2004, 2006). However, to draw adequate policy implications, it is important to know whether firms only need help in their first years or, instead, financial constraints are a persistent problem. While previous empirical studies provide some evidence that financial constraints do negatively affect the economic performance of start-ups during the first few years of existence, it is not well understood how the impact of financial constraints on economic performance changes with increasing firm age. Chapter 3 of this thesis analyzes this question based on an extensive data set for a cohort of Swiss start-ups that were observed during a period of ten years. Estimation results indicate that financial constraints are not only a problem of the first years. While the negative impact of financial constraints on firm survival disappears with increasing age of the firms, profit is persistently negatively affected by financial constraints. Ten years after firm foundation, financially constrained firms still have more problems to achieve profit break-even.

As most start-ups are not growth-drivers, the allocation of start-up subsidies has important policy implications. Innovative start-ups and not start-ups in general are considered to be drivers of innovation in existing industries and should also positively affect the creation of new industries (e.g., Acs & Audretsch 1990, Aghion et al. 2006, Schumpeter 1934). Especially for policy makers it is thus important to be able to identify the innovative start-ups. However, only a few studies analyze how such firms look like. As activities of start-ups are strongly related to firm founders, the study presented in Chapter 4 investigates this topic focusing on the innovation capability of firm founders. This study is again based on the data set for the start-up cohort 1996/97. One important feature of this data set is that it includes detailed information on the characteristics of up to three individual firm founders per firm.

The richness of the data makes it possible to describe in detail the characteristics of the whole founding team. Estimation results show that a combination of different founder characteristics such as university education (at best a combination of technical and commercial education), prior experience in R&D, and strong motivation to realize own innovative ideas increases innovative activities of start-ups by more than 40%. Hence, estimation results indicate that founder characteristics contain important information to identify innovative start-ups already in the beginning.

1 Introduction

Over the last twenty years a significant shift in the employment structure from low to high skills has taken place in advanced economies. Several factors are hypothesized to have driven this development. To mention are, on the demand side, a skill-bias of technical change (in particular the diffusion of "information and communications technologies", ICT) and a similar skill-bias of the redesign of workplace organization. Moreover, increasing specialization onto the production of knowledge intensive goods in the process of globalization also shifted labor demand towards higher skills. On the supply side, the long term trend towards higher education, as well as increasing preferences of employees for workplaces involving more autonomy, contributed to the observed increase in the employment of highly qualified personnel.

According to the literature, the demand side elements, in particular the diffusion of ICT and adaptations of workplace organization are the key factors driving the observed increase of the share of high skilled workers in total employment. Moreover, the interplay of these forces seems to accentuate the shift towards higher skills, although only a few studies find clear evidence for such complementarities (e.g., Arvanitis 2005, Bertschek & Kaiser 2004, Bresnahan et al. 2002, Piva et al. 2005). According to Caroli (2001), who discusses in detail the role of the variables involved, ICT may be considered as the enabling factor triggering off a redesign of workplace organization.

Many authors conceptualized these interrelated changes as a shift towards a "new firm paradigm", which they characterized using different labels: from a "mechanistic" to an "organic" firm structure (Burns & Stalker 1994), from the "mass production model" to the "flexible multiproduct firm" (Milgrom & Roberts 1990), or from a "tailoristic" to a "holistic" organization of work (Lindbeck & Snower 2000).

Since ICT is likely to provoke new challenges of adapting a firm's organization and human resource practices, there might be a sustained need to increase the stock of human capital of firms and the economy as a whole. Obviously, there are many different ways of achieving this objective. In Switzerland, similar to the other German-speaking countries, apprenticeship training is a widespread practice of skill formation. In Switzerland, about 70% of a cohort

strives for a vocational qualification. 75% of them pass through the apprenticeship system, 25% attend full-time vocational schools. The so-called “dual system” of apprenticeship-based vocational training combines education at a vocational school of one or two days a week, where general and occupation-specific skills are acquired, with work of three to four days a week in the training company, where learning is concentrated on occupation-specific and firm-specific skills.

For the future of this training system it is important to analyze whether apprenticeship training is an appropriate way of skill formation in a highly advanced knowledge-based economy where the new firm paradigm plays a significant role. In doing so, Chapter 2 of this thesis analyzes the impact of the three constituent elements of the new firm paradigm, i.e., intensive use of ICT, redesign of workplace organization and augmenting the input of human capital, on the provision of apprenticeship training. Furthermore, to analyze complementarities, interaction terms of human capital, ICT intensity and workplace organization are included.

The data used in this part of the thesis stem from two surveys conducted in 2000 and 2005, respectively, and cover the whole business sector of the Swiss economy. By merging the two cross-sectional data sets an unbalanced panel with about 3500 firms was constructed, of which more than 3000 could be used in model estimation. The data set is very rich in terms of variables that potentially explain the firms’ provision of apprenticeship training.

While human capital is a standard variable in the empirical literature dealing, by use of econometric methods, with a firm’s demand for apprentices (see, among many others, Beckmann 2008, Franz et al. 2000, Niederalt 2004), such studies did not pay much attention to the influence of ICT and workplace organization. To my knowledge, only Arvanitis & Stucki (2011) and Beckman (2002, 2008) included ICT as an explanatory variable and, so far, the impact of workplace organization has not been econometrically investigated at all. Furthermore, previous studies dealing with apprenticeship training did not take account of complementarities among the three core variables.

Against this background, Chapter 2 of this thesis provides new insights into the determinants of the firms’ provision of apprenticeship training by focusing on the relevance of the three constituent elements of the new firm paradigm and their interaction. Given the rich

database, it is possible to analyze the topic in a more differentiated way than it has been done in previous studies.

Important drivers toward such a “new firm paradigm” seem to be new firms. New firms are more likely to promote new and flexible organizational forms (Kim et al. 2006) and they are considered to increase innovation incentives and productivity growth in incumbent firms (Schumpeter 1934, Aghion et al. 2006). So far, however, little is known about these firms. The second part of this thesis analyzes probably two of the main questions in this area: what determines (a) the economic and (b) the innovation performance of start-ups?

The analysis of both questions is based on Swiss data for the start-up cohort 1996/97. This cohort was registered by the Swiss Federal Statistical Office and contains all “green-field” start-ups (i.e. mergers and manager-takeovers are not included) that were founded in this period. Hence, the data set allows to analyze the performance of start-ups on an empirical basis that is representative of all firms founded in 1996/97 in Switzerland. In the beginning the cohort included 7112 firms. Among these firms three surveys were conducted, the last one in 2006, nine to ten years after firm foundation.

The economic performance of new firms is analyzed with special focus on the impact of financial constraints. New firms generate only limited cash flows and seed capital is often too limiting for these firms. Thus, many start-ups must rely on the infusion of capital from external sources in order to survive. As particularly small and young firms have difficulties gaining access to external capital, start-ups are often financially constrained (e.g., Angelini & Generale 2008, Hallberg 2000, World Bank 2004). Economic performance of new firms should thus be strongly correlated with access to external capital.

A main factor for these financial constraints is the asymmetric information between the owners of the start-ups and external investors (e.g., Binks & Ennew 1996, Stiglitz & Weiss 1981). However, asymmetric information should primarily be a problem of the first years. With increasing age of the firms, outside investors get additional information about a firm’s quality and can adjust the terms of the financing contracts. Thus, for more mature firms costs of external capital should be lower and loan sizes should be less limited (see Brito & Mello 1995). Accordingly, the impact of financial constraints on success should decrease with increasing age of the firms.

Most previous empirical studies that deal with the impact of financial constraints on firm success primarily focus on established firms (e.g., Ayyagari et al. 2008, Becchetti & Trovato 2002, Hotz-Eakin et al. 1994 and Musso & Schiavo 2008). Fewer studies analyze this relationship for new firms (e.g., Aghion et al. 2007, Huynh et al. 2010, Hvide & Møen 2008, Saridakis et al. 2007, 2008). While both categories of studies provide some evidence that firm success is negatively affected by financial constraints, it is comparatively not well understood how that relationship changes with increasing age of the firms. The information whether firms only need help in their first years or, instead, financial constraints are a persistent problem, is of particular importance to draw adequate policy implications. To my knowledge, this question has not been empirically analyzed so far. Based on the data set for the start-up cohort 1996/97 that was observed during a period of ten years, Chapter 3 of this thesis attempts to fill this gap.

In addition to economic performance, innovation performance is a second important topic for research in the field of entrepreneurship. Most start-ups have more in common with self-employment than with the creation of high-growth companies (Shane 2009, p. 142). Hence, encouraging more people to become entrepreneurs is not necessarily the best policy. Especially for policy makers it is thus important to be able to identify firms with a high probability of enhancing economic growth. An important characteristic of such firms is their innovation performance. Innovative start-ups are considered to be important drivers of innovation in existing industries (Schumpeter 1934, Aghion et al. 2006) and should also positively affect the creation of new industries (Acs & Audretsch 1990). Despite this expected positive impact on economic growth, relatively little is known about the factors that determine the innovation performance of start-ups.

The innovative activity of start-ups might strongly depend on the characteristics of the firm founders, e.g., educational background and experience. The founders determine a firm's strategies and coordinate the resources to implement them (Barringer et al. 2004, Bergmann Lichtenstein & Brush 2001). Further, as start-ups are mostly small firms, the capabilities of the founders themselves serve as important resources to create a competitive advantage (Hadjimanolis 2000). Founders do not only decide whether to innovate or not, but are directly involved in the innovation process of the start-ups. Hence, knowing the innovation capability

of firm founders would make the identification of the innovative start-ups much easier, especially as most of these characteristics are easy to observe and remain constant over time. While there is empirical evidence for a link between management characteristics and innovation activities for established firms (e.g., Barker & Mueller 2002, Chen et al. 2008, Hadjimanolis 2000, Romijn & Albaladejo 2002), the impact of founder characteristics on innovation activities of start-ups is unclear. As the data set for the start-up cohort 1996/97 includes detailed information on the characteristics of individual firm founders, it seems well-suited to investigate this topic. This is done in Chapter 4 of this thesis, where the impact of founder characteristics on innovative activities of start-ups is analyzed.

2 The "New Firm Paradigm" and the Provision of Training: The impact of ICT, workplace organization and human capital*

2.1 Introduction

Over the last twenty years a significant shift in the employment structure from low to high skills has taken place in advanced economies. Several factors are hypothesized to have driven this development. To mention are, on the demand side, a skill-bias of technical change (in particular the diffusion of ICT) and a similar skill-bias of the redesign of workplace organization. Moreover, increasing specialization onto the production of knowledge intensive goods in the process of globalization also shifted labor demand towards higher skills. On the supply side, the long term trend towards higher education as well as increasing preferences of employees for workplaces involving more autonomy contributed to the observed increase in the employment of highly qualified personnel.

According to the literature, the demand side elements, in particular the diffusion of ICT and adaptations of workplace organization are the key factors driving the observed increase of the share of high skilled workers in total employment. Moreover, the interplay of these forces seems to accentuate the shift towards higher skills, although only a few studies find clear evidence for such complementarities (e.g., Arvanitis 2005, Bertschek & Kaiser 2004, Bresnahan et al. 2002, Piva et al. 2005). According to Caroli (2001), who discusses in detail the role of the variables involved, ICT may be considered as the enabling factor triggering off a redesign of workplace organization.

Many authors conceptualized these interrelated changes as a shift towards a "new firm paradigm", which they characterized using different labels: from a "mechanistic" to an "organic" firm structure (Burns & Stalker 1994), from the "mass production model" to the "flexible multiproduct firm" (Milgrom & Roberts 1990), or from a "tailoristic" to a "holistic" organization of work (Lindbeck & Snower 2000).

Since ICT is likely to provoke new challenges of adapting a firm's organization and human resource practices, there might be a sustained need to increase the stock of human capital of

* This chapter is based on Hollenstein & Stucki (2008).

firms and the economy as a whole. Obviously, there are many different ways of achieving this objective. In this paper we concentrate on apprenticeship training, which in Switzerland, similar to the other German-speaking countries, is a widespread practice of skill formation at the upper-secondary level.

In Switzerland, about 70% of a cohort strives for a vocational qualification. 75% of them pass through the apprenticeship system, 25% attend full-time vocational schools. The so-called "dual system" of apprenticeship-based vocational training combines education at a vocational school of one or two days a week, where general and occupation-specific skills are acquired, with work of three to four days a week in the training company, where learning is concentrated on occupation-specific and firm-specific skills.[1]

Since the 1990s, a certain shift in the content of apprenticeship training towards a higher proportion of general skill provision has taken place, in an attempt to better meet the demands of companies in a knowledge-based economy. To this end, the institutional arrangement of apprenticeship was adapted, with the introduction of a second, more demanding stream of training as the change with the most far-reaching consequences. It is based on an extension of the off-the-job apprenticeship training component and leads to a degree ("Berufsmatura") that guarantees free access to non-academic, vocational-oriented, tertiary-level education ("Fachhochschule", i.e. "university of applied sciences"). The creation of a "Berufsmatura" degree, which has been attained by one out of six apprentices in 2005, makes this type of secondary education more attractive for school leavers as well as for companies (for similar developments in Germany, see Finegold & Wagner 2002).

The present paper aims at identifying econometrically the determinants of apprenticeship training based on firm-level data. In doing so, we focus on the three constituent elements of the new firm paradigm, i.e. intensive use of ICT, redesign of workplace organization and augmenting the input of human capital. We try to explain why a firm does or does not provide apprenticeship training ("training *propensity*"), and, if doing so, to what extent a firm is engaged in this type of training ("training *intensity*"). The investigation is expected to give

[1] For an international comparison of several systems of vocational skill formation in European countries, see e.g. Steedman (2001, 2005), or Ryan (2001) who emphasizes the labor market experience of graduates from different types of vocational training.

some indication of the appropriateness of the apprenticeship system as a way of skill formation in a highly advanced knowledge-based economy where the new firm paradigm plays a significant role.

The data used in this study stem from two surveys conducted in 2000 and 2005, respectively, and cover the whole business sector of the Swiss economy. By merging the two cross-sectional data sets we got an unbalanced panel with about 3500 firms, of which about 3000 could be used in model estimation. The data set is very rich in terms of variables that potentially explain the firms' provision of apprenticeship training. Furthermore, the data set allows us to deal with potential econometrical problems such as endogeneity and firm heterogeneity.

The empirical literature dealing, by use of *econometric* methods, with a firm's demand for apprentices did not pay much attention to the influence of ICT and workplace organization. To our knowledge, only Arvanitis & Stucki (2011) and Beckman (2002, 2008) included ICT as an explanatory variable and, so far, the impact of workplace organization has not been econometrically investigated at all. In contrast, human capital is a standard variable used in such studies (see, among many others, Beckmann 2008, Franz et al. 2000, Niederalt 2004). On the other hand, we are not aware of any study dealing with apprenticeship training which takes account of complementarities among the three core variables.

Against this background, the paper provides new insights into the determinants of the firms' provision of apprenticeship training by focusing on the relevance of the three constituent elements of the new firm paradigm and their interaction. Given the rich database, we are able to analyze the topic in a more differentiated way than it has been done in previous studies.

The remainder of the paper is organized as follows: In Section 2.2, we present the conceptual background of the study as well as the hypotheses to be tested and the specification of the variables used in model estimation. In the next two sections, we shortly describe the database and expose the econometric procedure we applied in explaining a firm's training propensity and training intensity. The findings from model estimation are presented in Section 0. Finally, we discuss the main results and draw some conclusions.

2.2 Conceptual background and model specification

Basic approach

The seminal paper of Becker (1964) serves as starting point of our investigation. In his model, firms as well as apprentices conceive firm-based training as an investment in human capital enabling both parties to profit from higher productivity in the future. The firm, however, provides training only if the expected productivity gains are higher than the costs it has to bear. Whether this is the case depends on the type of skills generated by training (general vs. firm-specific knowledge), the costs of training (net of the trainees' productive contribution and subsidies) and the functioning of the market for skilled labor. If labor markets work perfectly well (what is assumed in Becker's model), a firm provides general (transferable) skill training only at zero net costs. It is not prepared to bear higher costs, since the trainees can leave the firm at the end of the apprenticeship at any time in search of higher wage offers.

In older empirical work the authors were puzzled by the finding that net costs of apprenticeship training were positive in many occupations. Therefore the investment theory of training has been further developed, with Acemoglu & Pischke (1998, 1999) probably the most influential contributions. This literature[2] explains the empirical finding of widespread net costs of firm-based training mostly with labor market imperfections: asymmetric information between the training firm and other companies about the trainees' productivity; unions and work councils enforcing firms to accept net training costs during apprenticeship; mobility costs (job search, costs of introduction at a new job; etc.). In addition, general and firm-specific skills often may be complements and are provided as a package (Kessler & Lülfesmann 2006).

In sum, these considerations imply that the *expected* net costs of (apprenticeship) training a firm has to bear, in the first place, depend on all factors that determine *future* demand for skilled labor. In accordance with the literature, we use the following categories of variables that may influence future demand for labor skills and therefore a firm's willingness to offer apprenticeship places: a) human capital endowment; b) usage of ICT; c) workplace

[2] See, for example, Beckman (2008) for a test of their propositions; for an overview of the most important approaches to the topic at hand see e.g. Franz et al. (2000) or Niederalt (2004).

organization; d) some specific control variables (physical capital, average wages, firm size, domestic/foreign ownership); e) dummy variables to capture effects not explicitly specified in the model (region, industry affiliation, time). In the following we discuss the impact of the explanatory variables and show how they are specified in the empirical model (see

for the exact definition of the variables).

Human capital

One of the constituent elements of the new firm paradigm is a shift from lower to higher skills. Since the share of employees holding high-level and medium-level degrees is correlated, a firm's human capital endowment should reflect the future demand for skilled labor in general. We thus posit the following hypothesis:

H1: A firm's human capital endowment is positively correlated with the provision of apprenticeship training.

In our model we use the share of employees holding a degree from tertiary education as proxy for a firm's human capital endowment (variable "*tertiary_share*"). In some instances, this share is transformed to five dummy variables "*tertiary_d*" representing different value ranges of "*tertiary_share*". Qualifications at the tertiary level are based, on the one hand, on academic education (primarily implying the production of general knowledge on top of general upper-secondary education), on the other hand, on more vocational-oriented education provided by universities of applied sciences and higher professional schools (to a large part as a follow-up to apprenticeship training). This second component, measured by its share in total tertiary education, weighs much more in Switzerland than in most other advanced economies.

Table 2.1: Variable definition and measurement

Variable	Definition / measurement
Dependent Variables	
training_propensity	Having at least one apprentice yes/no (training propensity)
training_intensity	Total number of apprentices (training intensity) *(only firms having apprentices*)
Independent Variables	
Human capital	
tertiary_share	Share of employees with a tertiary-level degree; logarithm
tertiary_d	Dummy variables for different shares of employees with a tertiary-level degree (reference group: "less than 3% (10th percentile)") tertiary_d1: 3-6% (25th percentile); tertiary_d2: 6-13%(50th percentile); tertiary_d3: 13-23.6% (75th percentile); tertiary_d4: 23.6-43% (90th percentile); tertiary_d5: 43-100% (100th percentile)
Information and Communication Technology (ICT)	
ICT_infrastructure	ICT infrastructure (four-level ordinal variable constructed as the sum of *four* dummies measuring the availability of different elements of ICT infrastructure: 1) personal computer; 2) Internet; 3) intranet; 4) extranet)
intranet_use_d	Share of employees regularly using the intranet (dummy variables with 0-20% as reference group: 21-60% (intranet_use_d1); 61-100% (intranet_use_d2))
Internet_variety	Variety and complexity of Internet applications (eight-level ordinal variable constructed as the sum of *eight* dummies measuring different types of Internet usage: 1) general search for information; 2) detailed search for market/price information; 3) presentation of the firm; 4) supply of product information; 5) internal communication; 6) further training; 7) E-purchasing; 8) E-selling)
ICT_total	Overall measure for ICT usage (sum of the standardized values (average 0; standard deviation 1) of all three ICT variables)
Workplace Organization	
Δ_hierarchical_levels	Change of the number of hierarchical levels in the preceding five years (decrease (value 1); otherwise (value 0))
Δ_delegation	Change of the degree of delegation of competencies in the preceding five years (increase (value 1); otherwise (value 0))
team_work	Incidence of team work (six-level ordinal variable, ranging from "very high" (value 5) to "inexistent" (value 0))
job_rotation	Incidence of job rotation (six-level ordinal variable, ranging from "very high" (value 5) to "does not exist" (value 0))
decentralization	Degree of decentralization of competencies: (mean of *seven* ordinal variables ranging from "line manager decides alone" up to "employee decides alone"; 5-point scale: 1) speed of work, 2) procedures of work, 3) distribution of tasks, 4) modality of the execution of tasks, 5) problems in production, 6) regular contact with clients, 7) complaints of clients)

WO_total	Overall measure for workplace organization (sum of the standardized values (average 0; standard deviation 1) of all five organization variables)
Control variables	
capital_intensity	Gross capital income per employee; logarithm
labor_costs	Labor costs per employee; logarithm
size_d	Dummy variables for six firm size classes based on the number of employees (reference group: "less than 20") 20-49 (size_d1); 50-99 (size_d2); 100-249 (size_d3); 250-499 (size_d4); 500-999 (size_d5); 1000 and more (size_d6)
foreign_owned	Foreign-owned firm yes (value 1), no (value 0)
region_d	Dummies for six regions (reference region: Ticino) Lac Léman (region_d1); Espace Midland (region_d2); North-western Switzerland (region_d3); Zurich (region_d4); Eastern Switzerland (region_d5); Central Switzerland (region_d6)
industry_d	Dummies for 27 industries (reference industry: "personal services")
year_2005	Time dummy for the year 2005 (reference: year 2000)
Instruments	
wage_individual_performance	Wage level primarily depends on individual performance five-level ordinal variable (level 1: 'very weak'; level 5: 'very strong')
industry level of intranet use	Average industry score of the share of employees regularly using the intranet (original variable is defined as "intranet_use")
industry level of decentralization	Average industry score of the degree of decentralization of competencies (original variable is defined as "decentralization")
industry level of tertiary share	Average industry score of the share of employees with a tertiary-level degree; logarithm (original variable is defined as "tertiary_share")

ICT usage

A more intensive use of ICT shifts the relative demand for qualified labor upwards. The literature mentions several properties of ICT driving the substitution of lower skills: a) ICT allows automating routine and well-defined tasks; it is much more difficult to do the same in case of complex tasks involving judgment and creativity (Autor et al. 2003, Bresnahan 1999, Bresnahan et al. 2002); b) highly computerized systems produce large quantities of data that need high-skilled workers to get adequately utilized (Arvanitis 2005); c) the adoption of ICT itself and its integration in the firm's productive system requires skilled workers, the more so as the use of ICT involves many uncertainties (Caroli 2001).

Whereas the positive effect of ICT on the demand for skilled labor as a whole is quite clear, it is less obvious which category of higher skills will "profit" from this technical

change. According to the results of the empirical work summarized in Arvanitis (2005), the demand for graduates from universities increases in parallel with a more intensive use of ICT, whereas the evidence with respect to medium skills is mixed (positive or neutral effect). However, the majority of empirical studies finds that the demand for skills at the higher intermediate level (vocational-oriented qualifications below a university degree but higher than medium skills) is positively affected. In view of these results we expect that the intensity of ICT usage is positively related to the demand for apprentices.

H2: Intensive use of ICT, in total as well as differentiated by specific dimensions of ICT use, positively affects a firm's demand for apprentices.

There are many possible indicators to capture the intensity of ICT use (see, e.g., Bocquet & Brossard 2007, European Commission 2007b; Hollenstein et al. 2003). In the present study we rely on three variables that are expected to positively affect the provision of apprenticeships (for details of measurement see Table 2.1): a) *"ICT_infrastructure"* captures a firm's endowment with technical ICT infrastructure (ordinal variable representing the number of up to four ICT elements: PC, Internet, intranet, extranet); b) *"intranet_use_d"* stands for the broadness of use of ICT measured by two dummy variables reflecting, respectively, "medium" and "high intensity" of use of the intranet; the latter dummy should exert a stronger (positive) influence on the provision of apprenticeships than the former. The two dummies are based on originally quantitative data of the share of employees regularly working with the intranet; c) *"Internet_variety"* indicates the variety and complexity of Internet applications. The measurement of this variable is based on detailed information about the purposes for which a firm employs the Internet, ranging from simple "search for information" up to more demanding functions like "E-selling"; the value of this ordinal variable simply represents the number of (up to eight) applications as shown in Table 2.1. Finally, to account for all three aspects of ICT at once, we also consider an overall measure of ICT use (*"ICT_total"*) calculated as the sum of the standardized values of the three individual ICT variables.

Workplace organization

According to Caroli (2001) flattening hierarchies, decentralization of decision making, greater involvement at the shop floor, collective work practices (teamwork, quality circles, etc.),

multi-tasking and job rotation are the core elements of a workplace organization that fits into a production system characterized by an intensive use of ICT. A redesign of workplace organization along these lines reflecting the new firm model is expected to increase, similar to a more intensive use of ICT, the demand for high skills at the expense of unskilled workers (skill-biased organizational change; see Piva et al. (2005) and the literature reviewed by these authors).

However, empirical studies show that the different aspects of workplace organization are not correlated to the same extent with the demand for higher skills. In the Swiss case, for example, teamwork and some aspects of delegation of competencies are positively related to the demand for high skills, whereas flattening of hierarchies or job rotation are not (Arvanitis 2005).

Against this background, we formulate two hypotheses with respect to the impact of new workplace organization on a firm's provision of apprenticeship training.

H3a: The redesign of workplace organization *as a whole* is positively related to apprenticeship training (reflecting the overall shift to higher skills induced by new workplace organization).

H3b: This holds true only for *some* of the five dimensions of workplace organization distinguished below. As a consequence, the overall effect, mentioned in H3a may not be very strong.

Our empirical model contains most of the above-mentioned organizational dimensions. At the level of the firm as a whole, we consider the "change of the number of hierarchical layers" having occurred during the five year period preceding the survey of 2000 and 2005, respectively ("*Δ_hierarchical_levels*"). The variable "*Δ_delegation*" captures the "change of the degree of delegation of competencies at the workplace" that happened in the course of the preceding five years. The two variables "*team_work*" and "*job_rotation*" stand for the current level of diffusion of teamwork (quality circles, semi-autonomous production teams, etc.) and job rotation, respectively. Moreover, we rely on a composite measure of the "distribution of competencies at the work place among managers and workers" ("*decentralization*"). This variable reflects a firm's assessment of the degree of decentralization of decision-making at the workplace in seven specific matters ("who decides on the work pace?", "who is

responsible for handling the complaints of clients? etc.; for details see Table 2.1). In addition to these variables that capture five specific aspects of new workplace organization, we also use an overall measure ("*WO_total*") which is calculated as the sum of the standardized values of the variables representing the individual elements of workplace organization.

According to hypothesis H3b, we do not expect that each dimension of workplace organization is positively related to the provision of apprenticeships. An insignificant relationship between "*Δ_hierarchical_levels*" and "*job_rotation*", respectively, and apprenticeship training would not be surprising. In case of "*Δ_ hierarchical_levels*" we would argue that a reduction of the number of hierarchical layers is an organizational change taking place at the level of the firm as a whole, whereas decisions on apprenticeship training are primarily related to the needs of the "shop floor"; the two decisions may thus hardly be correlated. Job rotation often is a measure implemented by the management for maintaining work motivation among low skilled workers (assembly-line workers, etc.); in this case, "*job_rotation*" would not be correlated with apprenticeship training or may even show a negative sign. Teamwork might be a very different matter. We presume that working in teams is an organizational arrangement that is well-suited for integrating apprentices, since team leaders and experienced co-workers are on the spot for supporting work-based training (positive sign of variable "*team_work*"). A high degree of decentralization of decision-making at the workplace ("*decentralization*"), at first sight, also may be expected to be conducive to apprenticeship training. However, depending on the hierarchical level at which it is decided on hiring apprentices, the training propensity may differ. One could argue that employees at low hierarchical levels have quite a weak preference for taking on apprentices because they are directly confronted with the costs of training (part of which they have to bear themselves). If decisions on the provision of training are made at relatively high hierarchical level to guarantee a longer-term view on the role of apprenticeship training, the preferences of the employees at the bottom of the hierarchy may be overridden. One also could argue that a work environment characterized by high autonomy and personal responsibility is very demanding and therefore not a suitable ambit for training apprentices. Similar arguments may apply to "*Δ_delegation*" ("degree of delegation of competencies increased"). In sum, though we still expect a positive sign for the variables "*decentralization*" and "*Δ_delegation*",

reflecting the general hypothesis of a positive effect of workplace organization on training propensity, we do not rule out that these two elements of workplace organization are not (or even negatively) correlated with apprenticeship training. The reasoning on possible effects of the various aspects of workplace organization implies that, in accordance with H3b, it is very likely that only part of the considered organizational aspects is positively related to the provision of apprenticeships.

Complementarities

To analyze how the combination of the three constituent elements of the "new firm paradigm" affects apprenticeship training, we also include interaction terms of human capital, ICT intensity and workplace organization. We expect that intensive use of more than one of the three elements increases the effect of the single variables.

H4: The interaction terms related to the summary measures of human capital, ICT and workplace organization are positively related to the provision of apprenticeship training.

Control variables

To avoid biased estimates for the core variables of the new firm model, we control for the impact of some specific firm characteristics (physical capital intensity, wage costs, firm size, foreign/domestic ownership) and include a series of dummy variables that control for effects not explicitly captured by the model.

Firstly, high wages per employee ("*labor_costs*") are negatively related to a firm's overall demand for labor and, other things being equal, to its need for qualified workers. Consequently, variable "*labor_costs*" is negatively correlated with the provision of apprenticeship training.

Secondly, in accordance with the bulk of empirical studies, we expect that the firm size (six firm size dummy variables "*size_d*") is positively correlated with the provision of apprenticeship training. Economies of scale in providing in-house training (availability of specialized instructors, specific training facilities, etc.) as well as some monopsony power on the (local) labor market and the existence of internal labor markets (both involving higher

retention rates) are probably the most important reasons for the positive correlation of the training provision and the firm size.

Thirdly, we expect that foreign-owned companies (variable "*foreign_owned*") less often provide apprenticeship training than domestic ones, since they usually are less familiar with the Swiss apprenticeship system and/or prefer to rely on "modes of training" taken over from their home-country.

Finally, we include dummy variables for a firm's affiliation to specific regions and industries as well as a time dummy. These variables should control for effects not *explicitly* captured by the model. The time dummy "*year_2005*" may reflect, in addition to time-varying firm heterogeneity, macroeconomic developments or changes in training policy in the period 2000–2005. The location of a firm, represented by six region dummies ("*region_d*"), should capture regional differences with respect to the institutional arrangements of apprenticeship training, the size and functioning of the regional labor market, the quality of the regional education system, etc. Besides, a firm's product market environment in terms of demand prospects, market structure and intensity of price and non-price competition may influence training activities (Gersbach & Schmutzler 2006). For example, favorable demand prospects for a firm's products should be positively related to its willingness to offer apprenticeships. We assume that such market-related variables, which, for data limitations, cannot be explicitly included in our model, are to a large extent industry-specific; hence, they are captured (in addition to other unspecified influences) by 27 dummies controlling for industry affiliation ("*industry_d*"). Furthermore, these variables should also capture effects of industry specific input prices that are not considered by other model variables.

So far the cost side of training provision has not been considered explicitly. Training costs vary among firms, in the first place, because of differences with regard to technological requirements (reflecting, for example, physical capital and ICT intensity), the structure of the local labor market for trainees and skilled workers (market power of local firms, regulations, etc.), the institutional framework for apprenticeship and other vocational training as well as for general education at the upper-secondary level, etc. We expect that such variations, to a

large extent, are industry-specific[3] and/or region-specific. Therefore we assume that the costs of training, as far as not yet captured explicitly by the variables representing the use of ICT or physical capital intensity, can be represented by region and industry dummies.

2.3 Data

The data used in this study were collected in the course of two surveys among Swiss companies conducted in 2000 and 2005, respectively. Both surveys were based on a disproportionately stratified random sample of firms covering the business sector (28 industries) and three firm size classes with a cut-off point of 20 employees.[4] We did not collect data from smaller companies as at least some of the organizational features we are interested in (e.g. "flattening hierarchical structures") are not relevant for most of them. The two surveys yielded data for 1688 and 1803 firms, respectively, representing response rates of 39.9% and 36.8%. The data were merged to a data set of 3491 companies, of which about 3000 could be used in estimating our training regressions. 76% of them provided apprenticeship training, with an average employment number of apprentices of about 7%. In most cases, the means of the variables used in model estimation are quite similar for the two cross-sections (see the descriptive statistics in Table A.1).

The two questionnaires, downloadable from www.kof.ethz.ch, contain questions about the adoption of several ICT technologies (Internet, intranet, extranet, etc.) and the intra-firm diffusion of some of these elements, the use of new organizational practices (team-work, job rotation, employees' involvement in decision-making, etc.) and the employees' degrees of general and vocational education. The two surveys also served to collect information on some financial variables and basic structural characteristics of firms.

[3] In Switzerland, regulation of vocational training is influenced to a significant extent by employer-employee agreements at industry level.

[4] The cut-off point of 20 employees for the two samples underlying the surveys of the years 2000 and 2005 has been determined according to the data reported in the Census of Enterprises of 1998 and 2001 respectively. Since, in some companies, the actual number of employees was lower at the time the surveys were carried out in comparison with the data from the preceding census, our data set also contains some firms with less than 20 employees (2.4% of all firms).

2.4 Econometric procedure

As mentioned in the introductory section, we seek to explain, firstly, a firm's *training propensity* indicating whether a firm does or does not provide apprenticeship training, and, secondly, *training intensity* reflecting the extent of a firm's involvement in training, measured as the total number of apprentices. As theory does not offer specific explanations for training propensity and training intensity, we use the same set of independent variables in the two empirical models.

In case of the *binary* dependent variable "*training_propensity*", estimating probit regressions is an adequate procedure. To take into consideration firm heterogeneity we use random-effects models. Likelihood-ratio tests showed that pooled probit models are not appropriate. However, pooled and random-effects model yield more or less the same results. We could not estimate fixed-effects models because we have only two years of data and, for most firms, the dependent variable "*training_propensity*" does not vary over time. Random-effects regression is thus the preferred method. Furthermore, for non-linear models we present the average marginal effects of the estimates as this allows us to better interpret the results, e.g. of the interaction terms.

The quantitative dependent variable "training_intensity" only refers to firms actually providing apprenticeship training. Consequently, selectivity bias may be a problem. We estimate a two-stage Heckman selection model to detect a potential bias (Heckman 1979). As shown in Table A.3, the intensity equation of the Heckman model is specified in the same way as our main model for "training intensity" shown in Table 2.3. The same set of explanatory variables is used in the selection equation, with the exception of the additional identifying variable "wage_individual_performance" (for definition see Table 2.1), in order to make sure that the estimated coefficients are reliable (see Wooldridge 2002a). This variable measures whether the wage level within a firm primarily depends on the individual performance of the employees. This should be a good instrumental variable, as the productivity of apprentices is limited and thus primarily firms with performance-linked payment should be willing to do apprenticeship training. Training intensity, however, should not be affected by this wage variable. Firms with performance-linked payments should have no incentives to prefer a certain type of employee. The hypothesized relationship can also be

observed in the data. The variable “wage_individual_performance" is statistically significant in the training propensity equation but is uncorrelated with training intensity. As the mills ratio is statistically insignificant at the 10%-level, there is no evidence for a selection bias.5 To consider firm heterogeneity we estimate for “training_intensity“ (as in case of “training propensity”) random-effects models, which, according to Lagrange-multiplier tests, are more appropriate than pooled models. Since five years elapsed between the first and the second survey, the number of observations that may be used for estimating fixed-effects models is substantially lower than in case of random-effects models (only about 18 percent of the firms responded in both surveys). Consequently, F-statistics are statistically insignificant indicating low model quality. We conclude that random-effects regression is the appropriate method to estimate the training intensity model.

Due to multicollinearity we had to perform separate estimates for the variables representing the disaggregated measures of ICT (see the correlation matrix in Table A.2). Furthermore, we tested the impact of disaggregated measures of workplace organization and interaction terms separately in the training intensity models.

A further potential problem is endogeneity that would imply inconsistent estimations. However, as the main objective of a firm is to produce and sell goods and/or services rather than to provide apprenticeship training, primarily economic objectives and not a firm’s training decisions should determine the structure of a firm. Therefore, the main results dealing with the impact of human capital, ICT endowment and workplace organization on training decisions should, at least, not be affected by reverse causality. Furthermore, endogeneity should be of little relevance, as we control in our models for different other factors that may affect apprenticeship training such as firm size or industry affiliation.

Nevertheless we test for endogeneity by applying the Rivers-Vuong-Test (Wooldridge 2002b, p.483) based on the null hypothesis that the core variables of our model are exogenous. In a first stage, we estimate instrument equations separately for each of three aggregate variables describing the “new firm paradigm”. We use industry averages as

[5] In the same way as the main model presented in Table A.3 we also tested the other models of Table 2.3 for selection bias. In all cases there is no evidence for a selection bias.

instruments.[6] All instruments in these equations fulfill the required conditions: they are correlated with the dependent variable in the instrument equation but uncorrelated with the dependent variable in the structural equation (training equation) and they are not correlated with the residuals of the endogenized training equation (for details of measurement see Table 2.1). In line with Cassiman & Veugelers (2002), we assume that each of these industry variables picks-up the effect of unobserved industry-specific attributes that contribute to the potential endogenous firm-specific variables (see Cassiman & Veugelers 2002, p. 1174). In a second stage, we include the residuals of the first stage in our training equation. To correct the standard errors of the estimated parameters we use bootstrapping. Under H_0 the residuals of the instrument equations and the residuals of the second stage equations are uncorrelated.

The tests for endogeneity in the training propensity and the training intensity equation refer to the summary measures of human capital (variable "*tertiary share*"), ICT (variable "*ICT_total*") and workplace organization (variable "*WO_total*"). In case of random-effects probit models, such a test is very time consuming; therefore we perform the test without correcting for firm heterogeneity. Using our instruments we throughout cannot reject the null hypothesis of exogenous variables (see Table A.4). Therefore we conclude that the three core elements of the "new firm paradigm" affect apprenticeship training directly and there is no problem with reverse causality.

[6] The industry is defined at the NACE three-digit sector level. For industries with a sample of less than ten firms, we used average scores on the NACE two-digit level. Furthermore, to ensure the exogeneity of these variables, the average scores are constructed as the average score from the firms responding in the sample, but excluding the values of the firm itself.

Table 2.2: Estimates of the propensity of apprenticeship training (average marginal effects)

Explanatory variables	Random-effects probit (1)	(2)	(3)	(4)	(5)	(6)
Human capital						
tertiary_share	0.010*** (0.003)	0.006* (0.003)		0.011*** (0.003)	0.010*** (0.003)	0.010*** (0.003)
tertiary_d1			0.095*** (0.030)			
tertiary_d2			0.126*** (0.028)			
tertiary_d3			0.126*** (0.030)			
tertiary_d4			0.123*** (0.034)			
tertiary_d5			-0.003 (0.038)			
ICT usage						
ICT_total	0.013*** (0.004)	0.016*** (0.005)	0.015*** (0.004)			
intranet_use_d1				0.051** (0.021)		
intranet_use_d2				0.015 (0.025)		
Internet_variety					0.015*** (0.005)	
ICT_infrustructure						0.021* (0.012)
Work organization						
WO_total	-0.006* (0.003)	-0.006* (0.004)	-0.005 (0.003)			
Δ_hierarchical_levels				-0.038 (0.025)	-0.038 (0.025)	-0.034 (0.025)
Δ_delegation				-0.008 (0.017)	-0.008 (0.017)	-0.007 (0.017)
decentralization				-0.038*** (0.013)	-0.037*** (0.013)	-0.038*** (0.013)
job_rotation				-0.005 (0.007)	-0.006 (0.007)	-0.005 (0.007)
team_work				0.012** (0.005)	0.011** (0.005)	0.012** (0.005)
Complementarity						
HC*ICT		-0.002* (0.001)				
HC*WO		0.000 (0.001)				
ICT*WO		-0.001 (0.001)				
Control variables						
labor_costs	-0.028 (0.028)	-0.022 (0.028)	-0.015 (0.028)	-0.023 (0.028)	-0.024 (0.028)	-0.023 (0.028)
foreign_owned	-0.115*** (0.024)	-0.115*** (0.024)	-0.107*** (0.024)	-0.109*** (0.024)	-0.108*** (0.024)	-0.112*** (0.024)
size_d1	0.075 (0.051)	0.078 (0.051)	0.077 (0.051)	0.064 (0.051)	0.072 (0.051)	0.066 (0.051)
size_d2	0.197*** (0.052)	0.200*** (0.051)	0.202*** (0.052)	0.185*** (0.051)	0.191*** (0.051)	0.188*** (0.051)
size_d3	0.297*** (0.053)	0.299*** (0.052)	0.303*** (0.052)	0.287*** (0.052)	0.295*** (0.052)	0.288*** (0.052)
size_d4	0.429*** (0.061)	0.431*** (0.061)	0.429*** (0.061)	0.415*** (0.061)	0.422*** (0.061)	0.422*** (0.061)
size_d5	0.364*** (0.067)	0.370*** (0.067)	0.365*** (0.066)	0.355*** (0.066)	0.360*** (0.067)	0.356*** (0.066)
size_d6	0.518*** (0.079)	0.526*** (0.079)	0.524*** (0.079)	0.526*** (0.079)	0.522*** (0.079)	0.524*** (0.079)
year_2005	0.027* (0.015)	0.027* (0.015)	0.024 (0.015)	0.030** (0.015)	0.030** (0.015)	0.031** (0.015)
Region dummies	yes	yes	yes	yes	yes	yes
Industry dummies	yes	yes	yes	yes	yes	yes
N	3005	3005	3005	3005	3005	3005
Wald chi^2	102.19***	100.47***	107.30***	99.42***	100.43***	98.26***
Rho	0.775	0.781	0.762	0.783	0.784	0.784
LR test of rho=0	116.48***	117.53***	111.49***	119.77***	121.76***	118.40***

Notes: See Table 2.1 for the variable definitions; to estimate marginal effects, we fixed the group specific intercept at 0, but otherwise averaged the marginal effects over the other explanatory variables; standard errors are in brackets under the coefficients; ***, **, * denotes statistical significance at the 1%, 5% and 10% test level, respectively.

Table 2.3: Estimates of the intensity of apprenticeship training

Explanatory variables	Random-effects GLS					
	(1)	(2)	(3)	(4)	(5)	(6)
Human capital						
tertiary_share	0.019**	0.022***		0.018**	0.018**	0.018**
	(0.008)	(0.008)		(0.008)	(0.008)	(0.008)
tertiary_d1			0.186**			
			(0.076)			
tertiary_d2			0.273***			
			(0.070)			
tertiary_d3			0.400***			
			(0.072)			
tertiary_d4			0.415***			
			(0.080)			
tertiary_d5			0.240**			
			(0.098)			
ICT usage						
ICT_total	0.009	0.005	0.006			
	(0.009)	(0.010)	(0.009)			
intranet_use_d1				0.059		
				(0.043)		
intranet_use_d2				0.040		
				(0.050)		
Internet_variety					0.005	
					(0.010)	
ICT_infrustructure						0.029
						(0.027)
Work organization						
WO_total	0.013**	0.014	0.011*			
	(0.007)	(0.009)	(0.007)			
Δ_hierarchical_levels				0.093*	0.096*	0.101*
				(0.053)	(0.053)	(0.053)
Δ_delegation				0.012	0.014	0.017
				(0.035)	(0.034)	(0.035)
decentralization				0.032	0.034	0.034
				(0.027)	(0.027)	(0.027)
job_rotation				-0.006	-0.006	-0.007
				(0.015)	(0.015)	(0.015)
team_work				0.009	0.009	0.008
				(0.011)	(0.011)	(0.011)
Complementarity						
HC*ICT		0.003				
		(0.002)				
HC*WO		-0.001				
		(0.003)				
ICT*WO		0.006*				
		(0.003)				
Control variables						
labor_costs	-0.292***	-0.296***	-0.314***	-0.299***	-0.291***	-0.293***
	(0.064)	(0.065)	(0.064)	(0.065)	(0.065)	(0.065)
foreign_owned	-0.067	-0.068	-0.070	-0.056	-0.053	-0.067
	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)
size_d1	0.448***	0.443***	0.482***	0.447***	0.452***	0.451***
	(0.142)	(0.141)	(0.139)	(0.141)	(0.140)	(0.141)
size_d2	0.789***	0.785***	0.840***	0.785***	0.793***	0.793***
	(0.144)	(0.144)	(0.142)	(0.143)	(0.143)	(0.143)
size_d3	1.432***	1.431***	1.471***	1.428***	1.436***	1.430***
	(0.145)	(0.145)	(0.142)	(0.144)	(0.144)	(0.144)
size_d4	2.115***	2.114***	2.149***	2.099***	2.112***	2.112***
	(0.149)	(0.149)	(0.146)	(0.149)	(0.148)	(0.148)
size_d5	2.794***	2.785***	2.823***	2.789***	2.799***	2.797***
	(0.160)	(0.160)	(0.157)	(0.160)	(0.159)	(0.159)
size_d6	4.074***	4.056***	4.114***	4.080***	4.093***	4.077***
	(0.181)	(0.181)	(0.176)	(0.180)	(0.179)	(0.180)
year_2005	0.049*	0.050*	0.040	0.048	0.050*	0.052*
	(0.029)	(0.029)	(0.029)	(0.030)	(0.030)	(0.030)
constant	2.438***	2.455***	2.516***	2.406***	2.295***	2.227***
	(0.748)	(0.750)	(0.737)	(0.757)	(0.746)	(0.754)
Region dummies	yes	yes	yes	yes	yes	yes
Industry dummies	yes	yes	yes	yes	yes	yes
N	2274	2274	2274	2274	2274	2274
Wald chi^2	2375.56***	2432.19***	2466.27***	2403.55***	2408.67***	2380.56***
R^2 within	0.167	0.165	0.179	0.167	0.171	0.167
Rho	0.597	0.597	0.599	0.595	0.596	0.594
LM test	130.55***	129.28***	121.60***	128.80***	129.25***	128.62***

Notes: See Table 2.1 for the variable definitions; the significance of the parameters is indicated with ***, ** and * resp. representing the 1%-, 5%- and 10%-level, respectively. Heteroskedasticity-robust standard errors are in brackets under the coefficients (White procedure).

2.5 Empirical results

2.5.1 Training propensity

Table 2.2 shows the results with training propensity as dependent variable. We primarily are interested in the influence on training propensity exerted by the variables representing the core dimensions of the new firm paradigm, i.e. human capital, ICT and workplace organization. Columns (1) and (2) refer to estimates where these core elements are specified as aggregate variables, with column (2) including complementarity effects. To better understand these main results, columns (3) to (6) contain the findings based on a more disaggregated specification of human capital, ICT and workplace organization.

Firstly, the results with respect to human capital are fully in line with a priori expectations; hypothesis H1 is thus confirmed. Firms with a high share of employees with tertiary education are significantly more likely to offer apprenticeships. Interestingly, the positive effect of tertiary education is increasing only up to a share of 6-13% (dummy variable "tertiary_d2") and becomes insignificant beyond the threshold of 43% ("tertiary_d5"). Hence, in case of very high levels of human capital input, the probability of apprenticeship training is low (i.e. not higher than for the reference group containing firms with a share of employees with tertiary qualifications below 3%).

The second element of the new system of production, i.e. the usage of ICT, also is positively related to training propensity what again matches the a priori expectations as stated in hypothesis H2. This holds true independently of whether ICT is specified as an aggregate variable ("ICT_total") or captured by three disaggregated measures. Training propensity is particularly high in firms with a broad ICT infrastructure (variable "ICT_infrastructure") and a high variety of applications of the Internet use ("Internet_variety"). The influence of the intra-firm diffusion of the intranet ("intranet_use_d") also is positive but, interestingly, the effect is not linear. We find a positive sign only at a medium intensity of intranet use, i.e. firms with regular intranet users in the range of 21% to 60% ("intranet_use_d1").

The third element – the redesign of workplace organization – is correlated with training propensity to a much lower extent than ICT usage, reflecting the fact that only some of the dimensions of workplace organization are correlated with training propensity. Working in a

team (variable “team_work”), as hypothesized, is a favorable environment for in-house vocational training. The data also confirm the argument that flattening of hierarchies (“Δ_hierarchical_levels”) and making use of job rotation (“job_rotation)” do not influence training propensity. The negative sign we find for the degree of decentralization of competencies (“decentralization”) and the insignificant coefficient of “Δ_delegation” are not in line with the overall hypothesis of a positive effect of workplace organization on training propensity. However, we also have put forward some arguments in favor of a negative sign for “decentralization” (“insufficient incentive at the shop floor to instructing apprentices”; “high autonomy of performing work tasks as a too demanding work environment for apprentices”), and similar arguments may hold true in case of “Δ_delegation”. Given the opposite effects of the individual elements of workplace organization, it is not surprising that the impact of aggregate workplace organization (“WO_total”) on training propensity is weak (with the negative effects slightly outweighing the positive ones). In conclusion, we do not find evidence for hypothesis H3a (positive overall effect of workplace organization). In contrast, hypothesis H3b is largely confirmed as the impact of the five organizational dimensions is different and more or less in line with our considerations in Section 2.2.

Fourthly, theory posits that the new firm model is characterized by complementarities between human capital, ICT and workplace organization, which should have an additional positive effect on the demand for skilled labor. Therefore, although the evidence for such effects is not overwhelming (see Section 2.1), we hypothesized that the complementarities positively affect training propensity (hypothesis H4). However, this proposition is not corroborated by our empirical estimates. The interaction term based on the aggregate measures of ICT and workplace organization (ICT*WO) as well as on human capital and workplace organization (HC*WO) are statistically insignificant (see column 2 in Table 2.2). We even get a negative effect of the interaction of human capital with ICT (HC*ICT). Hence, the combination of intensive use of ICT and a high share of employees with tertiary qualifications reduces the propensity of apprenticeship training. This negative interaction effect partially reflects the results we got for the dummies “tertiary_d” and “intranet_use_d”. These show that a very high share of employees holding tertiary degrees and a high intensity of intranet use do not positively correlate with the firms’ training propensity, whereas at an

intermediate level of the two variables both effects are positive. Hence, the finding that the interaction effect HC*ICT is negative, may be attributed to the behavior of the segment of firms having implemented the new firm model to a very high degree.

The effects of the control variables are in line with the expectations. An exception are average wage costs ("labor_costs") which, contrary to the expectations, do not negatively correlate with training propensity; we have no explanation for this result. As expected, training propensity increases with firm size more or less monotonically (dummy variables "size_d"). Foreign companies ("foreign_owned") are less involved in apprenticeship training than domestic ones, supporting the presumption that foreign enterprises are less familiar with the Swiss apprenticeship system. We also find a positive time effect for the year 2005, probably reflecting policy measures (campaigning among firms to offering apprenticeships, etc.) taken in the aftermath of the economic downturn of 2001/03. Finally, the dummies reflecting region and industry effects are statistically significant.

Summing up, the empirical results for the model explaining a firm's propensity to provide apprenticeship training supports three out of the five hypotheses we put forward in Section 2.2. There is strong evidence for a positive relationship with training propensity in case of two of the three core elements of the new firm paradigm, that is human capital (hypothesis H1) and ICT (Hypothesis H2: summary and differentiated measures). Only very intensive use of these two elements discourages firms from providing apprenticeship training. The effect of workplace organization is significant just for some of the organizational dimensions included in the model, with the effects more or less in line with our considerations in Section 2.2 (hypothesis H3b). Finally, we do not find evidence for positive interaction effects. On balance, we conclude that a change towards the new firm paradigm goes along with an increasing propensity of firms to provide apprenticeships.

2.5.2 Training intensity

In accordance with hypothesis H1, human capital positively affects the intensity of apprenticeship training ("tertiary_share"). Again, the effect of human capital ("tertiary_d") on training does increase up to a certain threshold (see Table 2.3). We find a pattern which is quite similar to that we found in case of training propensity. More specifically, firms with a share of employees with tertiary qualifications of more than 3% show significantly higher

training intensities than the reference group (below 3%). A new result is that firms with a share of highly qualified employees in the range of 3% to 13% ("tertiary_d1 and d2") have a significantly lower training intensity than firms with a share in the range of 13% to 43% ("tertiary_d3 and d4"), but this is not the case anymore beyond the threshold of 43% ("tertiary_d5"). The impact of human capital on training intensity is thus non-linear; it is stepwise increasing up to a share of 43% and is decreasing beyond this threshold value.

The redesign of the workplace organization measured at the aggregate level ("WO_total"), in line with hypothesis H3a, positively affects a firm's training intensity, whereas in case of training propensity we did not find such an effect. However, it is difficult to identify a single driver of this effect on a more disaggregated level. Despite the use of job rotation ("job_rotation"), all other measures of new workplace organization show a positive sign. Only a reduction of the hierarchical levels ("Δ_hierarchical_levels"), however, does significantly affect the training intensity of the firms. Hypothesis H3b is thus supported but the evidence is not overwhelming. One may ask why the sign of the aggregated effect of new workplace organization differs for training intensity (positive) and training propensity (negative). A reason for the negative effect in case of training propensity may be the high fixed costs of apprenticeship training in a work environment with a high degree of new workplace organization. Once the (initial) investment has been made, it pays off to increase the number of apprentices; hence the impact on training intensity is positive. Furthermore, it is surprising that "Δ_hierarchical_levels" does affect training intensity but not training propensity. A reason for this result may be that, in contrast to training propensity, intensive apprenticeship training is not a decision at the shop-floor and, hence, is more directly correlated with organizational changes taking place at the level of the firm as a whole.

ICT does not contribute to explaining training intensity, irrespective of the way it is measured ("ICT_total" vs. differentiated ICT variables). Hypothesis H2 is thus not confirmed. This result, which is in contrast to that for training propensity, has to be qualified as we identify an indirect effect of ICT. The interaction term of ICT and workplace organization (ICT*WO) is significantly positive (see column 3 of Table 2.3). Companies combining an intensive use of ICT with a redesign of workplace organization exhibit a higher training intensity than other firms. Hence, there is some evidence for the existence of

complementarities in explaining the apprenticeship training intensity what is in line with hypothesis H4.

The majority of the explanatory variables not related to the new firm paradigm show the expected influence on training intensity. As expected, the impact of "labor_costs" is significantly negative. The firm-size effect, as expected, differs among the two training variables. As for training propensity, training intensity monotonically increases with firm size. The impact of foreign ownership ("foreign_owned") is not statistically significant anymore, implying that foreign firms, once familiar with the Swiss apprenticeship system, behave in training matters like domestic firms. The region and industry dummies again are statistically significant. Finally, we again get a positive time effect (variable "year_2005").

Summing up, we find evidence for a positive impact on training intensity for two of the three categories of variables representing the new firm paradigm, i.e. human capital intensity (hypothesis H1) and workplace organization (hypotheses H3a and H3b). This is not the case for ICT if taken separately (direct effect). However, the combined effect of ICT and workplace organization (interaction term) is positive, pointing to the importance of complementarities in explaining the extent of apprenticeship training (hypothesis H4). Although not all hypotheses are confirmed, one may conclude that a transition towards the new firm paradigm is accompanied by an increasing intensity of apprenticeship training in firms providing this type of training.

2.6 Comparison with existing empirical literature

How do the findings with regard to the core variables of our model compare to the results of previous econometric work? The few studies taking account of ICT yielded mixed results. Beckmann (2002, 2008), based on a very rough measure of IT investments, got a positive effect on training propensity and intensity for a cross-section of German firms, whereas we did so only in case of training propensity. Arvanitis & Stucki (2011) found some weak evidence for a negative influence of the usage of Internet and intranet on training propensity based on a cohort of Swiss start-up firms. In view of the different measurement of ICT (investment in IT vs. several characteristics of ICT) and of specific sample characteristics

(new vs. established firms) a comparison of the results of these studies with our findings is not very meaningful.

It is even more difficult to compare the results with respect to the impact of workplace organization on the provision of apprenticeship training, since – to our knowledge – this paper is the only one that includes organizational variables in an *econometric* analysis of the topic. However, we notice that the results of this study are more or less in line with Finegold & Wagner (2002) who, based on a case study for the German banking sector, argue that hiring apprentices becomes more attractive when work organization gets more flexible and, in particular, when the incidence of teamwork increases.

Human capital is used as a variable to explaining why and to what extent firms offer apprenticeship places in quite a few studies (see, e.g., Arvanitis 2008, Beckmann 2002, 2008, Franz et al. 2000). In accordance with our results, these authors throughout find a positive effect of qualified as compared to unqualified labor.

2.7 Summary and conclusions

In this paper we analyze the impact of the tree constituent elements of the new firm paradigm, i.e. intensive use of ICT, redesign of workplace organization and augmenting the input of human capital, on the provision of apprenticeship training. The investigation is expected to give some indication of the appropriateness of the apprenticeship system as a way of skill formation in a highly advanced knowledge-based economy where the new firm paradigm plays a significant role.

In case of training *propensity*, there is strong evidence for a positive impact of two out of the three constituent elements of the new firm model: a) human capital intensity: positive effect of the employment share of workers with tertiary-level qualifications and b) ICT intensity: positive overall effect reflecting the availability of ICT infrastructure, the degree of intra-firm diffusion of the intranet and the variety of Internet applications. These results may be qualified by the observation that at the very highest level of both human capital and ICT intensity the propensity of apprenticeship training is low. The third core element of the new firm paradigm, i.e. the redesign of workplace organization, is less important as a determinant of training propensity. We find a significantly positive effect only for one of the five

organizational dimensions taken into consideration ("incidence of teamwork within the firm"), whereas the impact of a decentralization of competencies is negative. In sum, the results for training propensity suffice to conclude that apprenticeship training seems to be an appropriate way of skill formation in an advanced economy where the new firm paradigm plays a significant role. However, this may not be the case in the (technologically) most sophisticated segments of the economy.

In case of training *intensity* also two of the three core elements turns out to be statistically significant: a) human capital intensity: positive effect of the share of employees with tertiary education and b) workplace organization: positive effect of a reduction of the number of hierarchical levels. ICT does not directly influence the intensity of training provision, but there is evidence for a positive indirect effect of ICT reflecting the complementarity of ICT and workplace organization. Again we find some evidence (though weaker than in case of training propensity) that apprenticeship training is less widespread in technologically leading activities.

The findings with respect to ICT, workplace organization and human capital are encouraging for policy makers dealing with the Swiss apprenticeship system. They imply that the Swiss system is quite appropriate to accommodate the significant changes required for a transition to the new firm paradigm that plays an increasing role in economically advanced countries. This assessment may be qualified in one respect: the apprenticeship system without any doubt is very effective in providing skills in an advanced economy, but there is some evidence that this may not be the case in (technologically) leading-edge activities. It is up to further research to appraise this tentative conclusion. In any case, the reform of higher professional education in Switzerland set up in the late 1990s, particularly the establishment of universities of applied sciences (which provide science-based education mostly on top of apprenticeship training), is well-suited to counteract the (potential) weakness of the apprenticeship system we mentioned above.

3 Success of Start-up Firms: The Role of Financial Constraints*

3.1 Introduction

Many studies find evidence for the importance of start-ups. Start-ups positively impact economic growth and development (e.g., Audretsch et al. 2006, Gries & Naudé 2008) and they are important drivers of aggregate innovation and productivity (see Aghion et al. 2006). However, we can observe that many of these new firms fail in the initial years of life. Financial constraints should be an important reason for their failure. New firms generate only limited cash flows and seed capital is often too limiting for these firms. Thus, many start-ups must rely on the infusion of capital from external sources in order to survive. As particularly small and young firms have difficulties gaining access to external capital, start-ups are often financially constrained (e.g., Angelini & Generale 2008, Hallberg 2000, World Bank 2004). A main factor for these difficulties is the asymmetric information between the owners of the start-ups and external investors (e.g., Binks & Ennew 1996, Stiglitz & Weiss 1981). However, asymmetric information should primarily be a problem of the first years. With increasing age of the firms, outside investors get additional information about a firm's quality and can adjust the terms of the financing contracts. Thus, for more mature firms costs of external capital should be lower and loan sizes should be less limited (see Brito & Mello 1995). Accordingly, the impact of financial constraints on success should decrease with increasing age of the firms.

Most previous empirical studies that deal with the impact of financial constraints on firm success primarily focus on established firms (e.g., Ayyagari et al. 2008, Becchetti & Trovato 2002, Hotz-Eakin et al. 1994 and Musso & Schiavo 2008). Fewer studies analyze this relationship for new firms (e.g., Aghion et al. 2007, Huynh et al. 2010, Hvide & Møen 2008, Saridakis et al. 2007 and Saridakis et al. 2008). While both categories of studies provide some evidence that firm success is negatively affected by financial constraints, it is comparatively not well understood how that relationship changes with increasing age of the firms. The

* This chapter is based on Stucki (2009).

information whether firms only need help in their first years or, instead, financial constraints are a persistent problem, is of particular importance to draw adequate policy implications. To our knowledge, however, no study empirically analyzes this question so far. Based on an extensive data set for a start-up cohort that was observed during a period of ten years, this study attempts to fill this gap.

Our main research question asks whether the impact of financial constraints on the development of new firms decreases with increasing age of the firms. For this purpose, we analyze in a first step whether financial constraints affect the success of start-ups in the first years. First of all, we thus test whether our results confirm the negative impact found in most previous studies. In a second step, we then analyze the development of the effect of financial constraints on firm success when the firms grow older.

As the impact of financial constraints may differ between success measures, we use two different dependent variables: (a) firm survival and (b) to describe a firm's activity level, we use a dummy variable measuring whether a firm achieves profit break-even. To analyze the impact of financial constraints, we use separate measures for (a) external debt constraints and (b) venture capital constraints. Thus, a feature of our study is that we can analyze what kind of success is affected by which type of financial constraints.

The population we use in this study refers to the cohort of Swiss enterprises that were founded between 1996 and 1997. This cohort was registered by the Swiss Federal Statistical Office and contains all "green-field" start-ups (i.e. mergers and manager-takeovers are not included) that were founded in this period. Thus, we should be able to draw representative conclusions about the impact of financial constraints for start-ups. In the beginning the cohort included 7112 firms. Among these firms three surveys were conducted, the last one in 2006, nine to ten years after firm foundation. We thus have information on financial constraints at different stages in the development of the start-ups. This allows us to analyze whether the impact of financial constraints decreases when firms grow older. Potential econometrical problems of such an analysis like, e.g., endogeneity and sample selection are discussed in detail in a separate section.

With regard to our first research question, we find further evidence that the success of start-ups is negatively affected by financial constraints. Based on data of our first survey,

three to four years after firm foundation, we find that the achievement of profit break-even is negatively correlated with external debt constraints as well as with venture capital constraints. Firm survival is only affected by external debt constraints. In the follow-up surveys the effect of financial constraints on firm survival disappears. However, financial constraints persistently impact the profitability of these firms. In all (three) cross-sections, we find a significant negative correlation of financial constraints (debt and venture capital constraints) with the probability to achieve profit break-even.

The remainder of the paper is organized as follows: Section 3.2 presents the conceptual background of the empirical analysis. Section 3.3 describes the database. Section 3.4 contains specifications of the empirical framework used to describe the success of the firms. Section 3.5 presents the estimation results. Section 3.6 concludes our paper.

3.2 Conceptual background

The aim of this paper is to model the relationship between financial constraints and the success of start-ups embedded in a model of determinants of success. Our definition of financial constraints focuses on firms which are constrained by difficulties gaining access to external capital. Thus, financial constraints encompasses both, (a) a firm needs additional external capital and (b) has problems to acquire it.

Measurement of success

In the literature many different success indicators are used (for an overview see Albach et al. 1985 or Meyer 1994). In this study, the success of start-ups is measured as firm survival and whether a firm achieves profit break-even. The purpose of venture capital is, for example, not merely to survive but primarily to increase performance. Venture capital constraints may thus primarily affect a firm's activity level, but not survival. The use of two different dependent variables allows us to analyze what kind of success is affected by which type of financial constraints.

We have also tested the impact of financial constraints on employment growth. As growth of the firms in our sample is limited, access to external capital is of low importance. It is thus no surprise that we found no statistically significant impact of financial constraints on

employment growth. Furthermore, financial constraints do not affect the volume of sales and growth in sales of the firms in our sample. This may have two reasons. Firstly, sales of small firms are extremely volatile. The volume of sales at a certain point in time is thus not a representative measure of a firms' activity level. Secondly, as small firms often do not require audited financial statements, the exactness of absolute sales data is ambiguous. As our study bases on a representative sample of all start-ups in a certain period, most of the firms in our sample are small. Accordingly, data on the volume of sales is not a very good proxy to describe a firms' activity level. Therefore, we use the achievement of profit break-even instead of the volume of sales to describe a firms' activity level.

Success vs. financial constraints

Our conceptual framework builds upon the strategic management literature, which suggests that the performance of a firm depends on a firm's environment (external analysis), as well as on a firm's internal characteristics (internal analysis) (see Barney 1991). External analysis focuses on analyzing a firm's opportunities and threats within its competitive environment (e.g., Caves & Porter 1977, Porter 1980, 1985). In the resource-based view, the individual firm resources – including human capital, physical capital and organizational capital resources – enable the firm to create and implement strategies that improve its competitiveness (see Barney 1991). Hence, lack of external financial resources should directly affect the success of the firms.

According to the literature, difficulties gaining access to external capital are caused through asymmetric information between the owners of the start-ups and outside investors (e.g., Binks & Ennew 1996, Stiglitz & Weiss 1981). There are several reasons for a high level of asymmetric information. Firstly, the fact that start-ups have no track record directly leads to higher evaluation costs. A study of the World Bank finds that the availability of credit history information reduces processing time, processing costs and default rates of credit bureaus by more than 25 percent (World Bank 2006, p.13). Secondly, as small firms often do not require audited financial statements, start-ups do not have much publicly visible information. Under these circumstances, it is difficult for outside investors to evaluate the creditworthiness of start-ups. Given the high failure rate of these firms, agency costs of

external capital relative to capital size can be substantial. As a consequence, access to external capital may be expensive or even rationed.

In the case of innovative start-ups, asymmetric information is not the only reason for problems to get access to external capital. Innovative start-ups may have problems to acquire external debt capital, even if asymmetric information is limited. Because innovative start-ups sell new products, it is difficult to judge whether their innovations will be successful or not. Venture capital can solve this problem of high risk. In exchange for the high risk that venture capitalists assume by investing in innovative start-ups, venture capitalists usually get a significant portion of the company's ownership. Furthermore, venture capitalists mostly have sector-specific expertise that enables them to better evaluate the risk of an investment. Thus, for innovative start-ups primary access to venture capital is important. The availability of venture capital, however, is strongly limited (OECD 2008, p.156).

Start-ups generate only limited cash flows. Therefore, firms with financial constraints will be less able to sustain unexpected losses, even for a limited period (see Mata et al. 1995). Furthermore, constrained firms need to cut costs in order to generate the resources they cannot raise on the financial market. Financial constraints should thus limit a firm's investments in productivity-enhancing projects, what in turn negatively affects firm success (see Holtz-Eakin et al. 1994, Aghion et al. 2007). To analyze the impact of different forms of financial constraints we distinguish between external debt constraints and problems to acquire venture capital.

The discussion above allows us to formulate the following hypothesis:

H1: Financial constraints do negatively affect the success of start-ups.

Such a negative effect of financial constraints on the success of new firms was found in most previous empirical studies (e.g., Aghion et al. 2007, Huynh et al. 2010, Hvide & Møen 2008, Saridakis et al. 2007 and Saridakis et al. 2008). The study of Cressy (1996) is an exception. Cressy (1996) finds that financial capital does not affect survival of start-ups if the model controls for the human capital of the firms. He thus concludes that "a reason for the divergence of empirical results in the area may be the failure to test a sufficiently rich empirical model" (Cressy 1996, p.1266). To counter this critique, we include our measures of financial constraints in an extensive base model that controls in detail for human capital and

founder characteristics (see Section 3.4.1 for a detailed description of the model specification).

Persistence of the impact of financial constraints

With increasing age, firms gain a track record and outside investors learn about the firm, wherefore the level of asymmetric information decreases. Unknown firms should thus "face greater liquidity restrictions and higher cost of capital than more mature firms with well-known prospects" (Brito & Mello 1995, p.544). Furthermore internal financial flows should increase with increasing age of the firms, wherefore dependency on external capital would decrease. A track record should also reduce the risk of an investment in innovative start-ups and hence decrease their dependence on the availability of venture capital. In accordance with Brito & Mello (1995), we thus expect that financial constraints are negatively correlated with the age of the firms. Accordingly, the impact of financial constraints on the success of the firms should decrease with increasing firm age.

We thus formulate the following hypothesis:

H2: The effect of financial constraints on the success of start-ups is strongest in the first years after firm foundation.

Previous empirical studies analyze the impact of financial constraints either for established firms or for start-ups. To our knowledge, no other study empirically tests this hypothesis so far.

Differences between the two dependent variables

As firms probably stay in the market even though they sustain a loss in a certain period, survival is a more fundamental success measure than profit. This may affect our results in two ways. With respect to hypothesis 1, we would expect that the survival of firms is predominantly affected when a firm faces serious financial constraints, while the achievement of profit break-even may already be affected by a lower level of financial constraints. Secondly, as the level of financial constraints should decrease with firm age (hypothesis 2), we would not be surprised when the impact of financial constraints on the survival of these firms becomes insignificant at an earlier stage, than the impact on the achievement of profit break-even.

3.3 Description of the data

3.3.1 Construction of the data set

The population we use in this study refers to the cohort of Swiss enterprises that were founded between 1996 and 1997. In the beginning the cohort included 7112 firms. This cohort was registered by the Swiss Federal Statistical Office and contains all "green-field" start-ups (i.e. mergers and manager-takeovers are not included) that were founded in this period and had conducted the business activities at least twenty hours a week.[1]

In 2000, we checked which firms of this cohort still existed. We defined a firm to have exited when it did not answer our questionnaire and (a) was not registered in the Swiss Commercial Register anymore or (b) the exit was verified by telephone. 3288 (46.2%) of these start-ups were still in business in 2000. Among the firms that still existed by that time, data were collected by means of a postal survey. 49.4% (1625) of the firms answered the questionnaire. 1339 (82.4%) of these firms survived the next three years. In 2003 a follow-up survey was conducted among these firms. Answers were received from 70.6% (945) of the firms. In 2006, nine to ten years after firm foundation, 857 (90.7%) of the participants of the 2003 survey still existed. 73.5% (630) of them were willing to fill out a third questionnaire. For some firms we thus have data at different points in time. For firms which dropped out of the sample we know whether the firm still existed at time of drop out and also whether the firm survived the following period up to 2006.

The questionnaire covered questions about basic firm characteristics, firm success and activity level, resource endowment, innovative activities, the market environment and financial constraints.[2] In 2000, the questionnaire included some additional questions about the founder characteristics (e.g., gender, age, education, experience and the wealth of the firm founders).

3.3.2 Measurement of financial constraints

Our measures of financial constraints are based on self-reported data. In each cross-section firms were asked to report on a five-level Likert scale the importance of different forms of

[1] The firms were recorded by the Swiss Federal Statistical Office independently whether they were enrolled in the Swiss Commercial Register or not.
[2] The questionnaires are available in German, French and Italian at www.kof.ethz.ch/surveys/ structural/panel.

financial constraints with respect to the preceding three years. For external equity, we have information on the importance of limited availability of venture capital funding (VC_CONST). This question implicates that a firm is effectively looking for venture capital. Thus, primarily firms that regard themselves as potential receivers of venture capital should feel constrained with respect to our measure. For external debt capital, what for most of the start-ups in our sample is the more important source of external capital, we have more detailed information. We know the importance of different reasons for external debt capital constraints. These are unfavorable credit conditions (CRED_COND), a too low credit line (CRED_LINE) and insufficient information about external debt financing options (DEBT_INFO). This information allows us to separately analyze the impact of different types of external debt constraints, in particular price and quantity constraints. To be able to test the impact of external debt constraints as a whole, we further calculate an overall measure of external debt constraints (DEBT_CONST). The overall variable is calculated as the sum of the standardized values (average 0, standard deviation 1) of the three detailed variables.

Self-reported data has been extensively used in the literature and is also common to measure financial constraints (e.g., Becchetti & Trovato 2002, Campello et al. 2009, Saridakis et al. 2008, Winker 1999). An advantage of self-reported data is that firms know best whether they are financially constrained or not. As financial constraints depend not only on the availability of external capital, but also on whether the firms effectively need additional capital, it is difficult to find objective measures that completely capture financial constraints. This applies all the more, as we have separate measures for different sources and different types of constraints. Subjective assessment of financial constraints, however, may reduce comparability between firms. Potential problems of survey data include that the measures of financial constraints may share a common unmeasured cause with firm performance (see, e.g., Hallward-Driemeier & Aterido 2009). To deal with such concerns we test our measures of financial constraints for endogeneity. The testing procedure is described in Section 3.4.2.

Table 3.1: Variable definition and measurement

Variable	Definition/ measurement
Dependent variables	
SURVIVING	Firm survives next three years yes/no
BREAK	Firm achieves profit break-even at time of survey yes/no
Independent variables	
MAIN	At time of firm foundation founder worked on a regular basis yes/no
UNEMPLOY	Founder was unemployed before firm foundation yes/no
LAGE	Average age of the firm founders; natural logarithm
GENDER	Gender of the firm founders: male/female (value 1: 'male'; value 0: 'female'; the most frequently reported gender is regarded as representative for the firm founders; when the number of 'females' equals the number of 'males' we set 'female')
QUAL	Employees with tertiary-level education yes/no
R&D	R&D activities yes/no (in previous period)
NP	Development and introduction of new products yes/no (in previous period)
MP	Development and introduction of modified existing products yes/no (in previous period)
PCOMP	Intensity of price competition (transformation of a five-level ordinal variable (level 1: 'very weak'; level 5: 'very strong') to a binary variable (value 1: levels 4 and 5 of the original five-level variable; value 0: levels 1, 2 and 3 of the original variable)
NPCOMP	Intensity of non-price competition (original and transformed variables as for PCOMP)
LCAP	Volume of seed capital; natural logarithm
AG	Public limited company (dummy variable with sole proprietorship as reference legal form)
GmbH	Private limited company (dummy variable with sole proprietorship as reference legal form)
OTHER	Other legal forms (for example general partnership) (dummy variable with sole proprietorship as reference legal form)
LSIZE	Number of employees; natural logarithm
IND	Dummies for three industries (construction (IND_1); modern services (IND_2); traditional services (IND_3); reference industry: manufacturing)
DEBT_CONST	Importance of external debt constraints in the preceding three years (sum of standardized values (average 0, standard deviation 1) of three ordinal variables: 1) unfavorable credit conditions, 2) credit line too low, 3) insufficient information about external debt financing options)
CRED_COND	Importance of unfavorable credit conditions in the preceding three years (five-level ordinal variable, ranging from "very high" (value 5) to "very low" (value 1))
CRED_LINE	Importance of a too low credit line in the preceding three years (original variable as for CRED_COND)
DEBT_INFO	Importance of insufficient information about external debt financing options in the preceding three years (original variable as for CRED_COND)
VC_CONST	Importance of venture capital constraints in the preceding three years (original variable as for CRED_COND)
REG	Dummies for six regions (Lac Léman (REG_1); Espace Midland (REG_2); North-western Switzerland (REG_3); Zurich (REG_4); Eastern Switzerland (REG_5); Central Switzerland (REG_6); reference region: Ticino)
BUS_PLAN	Firm started with a business plan yes/no
UNI	Firm was founded to realize ideas from research at university yes/no
T_MARK_SHARE	Firm targets a high market share (five-level ordinal variable, ranging from "very high importance" (value 5) to "very low importance" (value 1))
T_NEW_TECH	Firm targets the application of new technologies (original variable as for T_MARK_SHARE)
T_NEW_PROD	Firm targets the development and introduction of new innovative products/services (original variable as for T_MARK_SHARE)
WEALTH_SHARE	Share of founders with private assets at time of firm foundation
SHORT	Shortage of high-qualified personnel yes/no (the variable is based on the two ordinal variables 'high-qualified personnel is too expensive' and 'high-qualified personnel is too difficult to find'; we calculated the average of the scores for these two variables; then transformed the mean of these two five-level ordinal variables (level1: 'very weak'; level 5: 'very strong') to a binary variable (1: values higher than 3 of the mean variable;0: values 3 and lower than 3))
INSAMPLE	Firm is still in the sample in the following cross-section yes/no

3.3.3 Characteristics and development of the start-ups

Most of the start-ups in the data set are firms in the service sector. In each point of time they represent about 83% of the observations. About 9% belong to the construction sector, the remaining 8% to the manufacturing sector. These shares remained almost constant during the period 2000–2006. In the service sector the sub-sector of modern (knowledge-intensive) services (e.g., banking and insurance, business services) has a larger share than the sub-sector of traditional services (e.g., trade, hotels and catering); the share of modern services increased considerably between 2000 and 2006. In the manufacturing sector there are more low-tech than high-tech start-ups.

The observed start-ups are for the most part small firms. In each survey more than 80% of the enterprises employed less than five employees (measured in full-time equivalents). The average firm size only slightly increased from one period to the next. While in 2000 the firms had on average a size of 2.6 employees, the average size increased to 3.3 employees in 2003 and 4.8 employees in 2006. In 2006, ten years since their foundation, only 6.7% of the firms employed more than ten employees.

On average nearly 20% of the firms said that they face large difficulties (value 4 or 5 on respective Likert scale) gaining access to external debt capital. As expected, innovative firms have more problems to acquire external debt capital. External debt constraints of firms with R&D activities are significantly higher than the constraints of firms without R&D activities. As venture capital is primary to finance innovative start-ups, fewer firms are constrained by venture capital. About 10% of the firms were seriously constrained by the availability of venture capital. As expected, financial constraints of the start-ups in our sample decrease with firm age. While in 2000 external debt constraints were for 19.4% of the firms of high importance, the share decreased to 15.1% in 2003 and 14.5% in 2006. At the same time, the share of firms with serious venture capital constraints decreased from 10% in 2000 to nearly 6% in 2006. The decrease is not only caused through sample selection. We can also observe decreasing financial constraints when we include only firms which answered all three questionnaires. Potential econometrical problems of our financial constraint variables such as sample selection and endogeneity are further discussed in Section 3.4.2.

3.4 Econometric framework

3.4.1 Model specification

To capture different aspects of firm success we estimate our model using two different dependent variables. SURVIVAL is a binary variable measuring whether a firm does or does not survive the next three years. BREAK is a dummy variable measuring whether a firm achieves profit break-even at time of survey. To be able to test whether the impact of financial constraints changes with firm age, we estimate the model separately for each cross-section. BREAK is modeled separately for cross-section 2000, 2003 and 2006, whereby data for the dependent and independent variables come from the same cross-section.[3] As firms that left the market between two subsequent surveys did not answer the questionnaire at the end of the period, survival models include independent variables observed for all units at the beginning of a period. Since we have no survey data for 1996/97, we cannot explain firm survival between 1996/97–2000. Thus, we model firm survival for the periods 2000–2003 and 2003–2006 only.

We use in all models the same set of independent variables. As described in Section 3.3.2, we test the impact of financial constraints on firm success by including five variables. The effect of external debt constraints is analyzed using the overall as well as the detailed variables. To capture different effects on firm success, we include the variables measuring financial constraints in an extensive base model (for descriptive statistics and a detailed definition of the variables we refer to Table 3.1 and Table B.1, respectively). Following the theoretical literature, and in accordance with empirical studies (see, e.g., Brüderl et al. 1992, Marmet 2006, Stearns et al. 1995 and Saridakis et al. 2008 for a similar approach), we include the following categories of control variables: founder characteristics, human capital endowment, firm strategy, market conditions and general firm characteristics. To capture industry specific effects, we further include dummies controlling for industry affiliation.

Founder characteristics. According the motivation theory we expect that firm founding as an act from necessity is negatively correlated with firm success (e.g., Gartner et al. 1992, Johnson 1986, Schjoedt & Shaver 2007). In our model we measure this effect by including

[3] An exception is the firm size variable that is included with a time lag of three years.

the employment status of the firm owners before firm creation (UNEMPLOY). Whether founders work on a regular basis or not (MAIN) measures a founder's dedication to the firm and the seriousness of the founded firm (Brüderl et al. 2007, p.194). Age of the founders (LAGE) can be seen as a proxy for professional experience, and thus should be positively correlated with firm success. On the other hand, some age-related decisions such as exits to go into retirement negatively affect the current success measures of the firms. Since age-related exits are probably not caused through lack of success, such exits may distort the use of SURVIVAL as success measure. LAGE should capture this effect of voluntary firm exits in the survival models.[4] GENDER controls for effects through gender specific skills (e.g., Cooper et al. 1994).

Human capital. Through formal education, people acquire skills that help to recognize opportunities in the surrounding environment (Baptista et al. 2007, p.9). Such skills are important to successfully compete with other firms. All in all, firms with tertiary educated employees (QUAL) should thus be more successful.[5]

Strategy variables. Innovation variables measure the ability of a firm to use its resources to create capabilities (see Audretsch & Mahmood 1995). According to Buddelmeyer et al. (2010) effects on success may differ between innovation input and output. While innovation output by itself is a successful innovation, current innovation investments implicate a certain risk of failure, what indicates more uncertain returns. To completely capture innovation effects, we include in our model measures of innovation output as well as of innovation input. Innovation output is measured by the introduction of new (NP) and modified products (MP). R&D activities (R&D) indicate innovation input. Hence, we expect that innovation output is positively correlated with our success variables. Innovation input may have a negative impact.

Market conditions. The intensity of competition differs among stages of an industry's life cycle. The expectation of industry life cycle models is that in an early stage firms compete on product differentiation. As industries mature, products of different firms get more similar and

[4] To capture at the same time the effect of professional experience and age related decisions, we alternatively split the age variable into different dummy variables (see footnote 12).

[5] As most firms in our sample are small, QUAL captures to a large extent also the impact of the education level of the firm founders. As measures for the education level of the firm founders and our measure for the qualification level of all employees are strongly correlated, it was not possible to control for both effects separately.

competition shifts from product innovation to process innovation (e.g., Adner & Levinthal 2001, Cusumano et al. 2006, Utterback & Abernathy 1975). It should be easier for start-ups to establish and maintain a competitive advantage in young markets. We expect a positive impact of the intensity of non-price competition (NPCOMP) on firm success and a negative effect of the intensity of price competition (PCOMP).

Firm variables. It depends on the legal form of a company to what extent founders are liable in case of failure. Founders of firms with limited liability (AG, GmbH) should be primary interested in projects with a high anticipated return, while the risk of failure is of lower importance (see Stiglitz & Weiss 1981). For example, full liability (sole proprietorship) may positively impact voluntary exits (see Harhoff et al. 1998). We thus expect that full liability is negatively correlated with firm survival. The impact of the legal form on profit is not a priori clear.

The “liability of smallness” hypothesis assumes that business size affects firm success because larger firms have more resources to manage bad times (e.g., Aldrich & Auster 1986, Brüderl 2007). In accordance with this hypothesis, a firm’s financial strength serves as a buffer against external shocks. Further, a certain internal financial buffer reduces dependence on external capital. Hence, we expect a positive impact of firm size (LSIZE) and volume of seed capital (LCAP) on firm success.

3.4.2 Econometric procedure

To take into account the binary character of the two dependent variables measuring firm survival (SURVIVAL) and whether a firm achieves profit break-even (BREAK) we estimate probit models. Each cross-section reflects a further stage in the development of the start-ups. Differences of the results over these three points in time should thus represent different effects on firm success at different development stages. This allows us to analyze whether the impact of financial constraints on the success of start-ups changes with increasing age of the firms.

Due to multicollinearity we have to conduct separate estimates for the different variables measuring financial constraints (see correlations in Table B.6). The base model is not affected by multicollinearity.

Correcting for selective attrition

Between two subsequent surveys some firms disappeared from the market and some other did not want to participate to our survey anymore. The question is whether the remaining samples are still representative. If determinants of selection are correlated with our success measures, attrition is selective, and traditional econometrical techniques will lead to biased and inconsistent estimates.

When a firm refused to answer a questionnaire, we only know if this firm still existed, but we have no observations for the other variables in our models. Thus, the equation that describes whether a firm is still in the sample or not (selection equation) and the equation that describes the success of the start-ups (strategy equation) cannot be identically specified and we cannot use a Heckman procedure to detect a potential selection bias (see Wooldridge 2002a, Briggs 2004).

In the survival models we only have attrition through non-response. Because we know for firms which answered the previous questionnaire, as well as for firms which did not answer the questionnaire, if they survived the following period, we can analyze whether the survival probability is significantly different for respondents than for non-respondents. Using chi-square tests, we find no evidence for a selection bias.[6]

In the profit break-even models data may suffer from selective attrition through both non-response and non-survival. Following Wooldridge (2002a, p.581) a test for selective attrition is to insert a selection indicator as an additional explanatory variable in our base model, run the regression and test the significance of the coefficient of the selection indicator. As a selection indicator we use the dummy variable INSAMPLE that takes the value one if a firm is still in our sample in the following cross-section and zero if not. Because we have no such indicator for cross-section 2006, we can only apply this test for cross-sections 2000 and 2003. The test results indicate that selective attrition may be a problem in the profit break-even models. The coefficient of the selection variable for both cross-sections is significant (see Table B.1 in the appendix).

[6] Further, we also analyzed the impact of attrition on survival using multiple regression models. Since we have only some basic data for firms which did not answer our questionnaire, the model quality was not good enough to interpret the relevant coefficients.

To correct the profit models for attrition bias, we apply the inverse probability weighting approach (see Wooldridge 2002a, 2007). Following this approach, we estimate in a first step the probability that a firm has not disappeared so far (retention probability). In a second step we weight each firm with the inverse of this estimated probability. The idea is that firms which have a higher attrition probability are underrepresented in the sample and therefore get more weight in the models. Wooldridge shows that the weighted estimator is consistent if the assumption called "selection on observables" holds. Under this assumption a vector of variables observed for firms that are in the sample in the first period t=1, z_{i1}, predicts selection at time t, so that all variables in the consecutive models at time t, (y_{it},x_{it}), are independent of selection (Wooldridge 2002a, p.587). To allow the explanation of selection by past outcomes of (y_{it},x_{it}), z_{it}, we must further assume that selection at time t is independent of future values of z_{it} and (y_{it},x_{it}). When s_{it} is a selection indicator, where s_{it}=1 if (y_{it},x_{it}) are observed in period t, the probability of selection then is defined as

$$P(s_{it}=1 \mid \ v_{i1},...,v_{iT}, s_{i,t-1}=1) = P(s_{it}=1 \mid \ z_{it}, s_{i,t-1}=1) \tag{1}$$

where

$$v_{it} \equiv (y_{it}, x_{it}, z_{it}). \tag{2}$$

In our data we have a two-stage selection between two cross-sections. In a first stage, firms which did not survive a period exit our sample. In a second stage, firms which did not answer our questionnaire at the end of the period drop out. The retention probability equals the probability to get an answer ($ANSWER_{it}$=1), conditional on the probability that the firm still exists in that period ($SURVIVAL_{it}$=1). To calculate the probabilities of the different outcomes we estimate a multinomial probit model (see Kapteyn et al. 2006 for a similar approach).[7] The retention probability then can be calculated as

$$P(ANSWER_{it} \mid \ SURVIVAL_{it}) = \frac{P(ANSWER_{it} \cap SURVIVAL_{it})}{P(SURVIVAL_{it})} = \frac{P(ANSWER_{it} \cap SURVIVAL_{it})}{1 - P(NONSURVIVAL_{it})}. \tag{3}$$

[7] The multinomial probit procedure seems to be superior to a multinomial logit because it does not assume independence of irrelevant alternatives (IIA) (Greene 2003, p. 727).

We assume that the response behavior depends on the same determinants as firm survival. In a first step we used the whole success model to estimate the multinomial probit model. To increase the quality of our estimates, we excluded in a second step insignificant variables. Estimation results are presented in Table B.3.

Following Wooldridge (2002a, p.589), in cases where attrition is an absorbing state[8], the probabilities used in the inverse probability weighting procedure can be calculated as

$$\hat{P}_{it} \equiv \hat{\pi}_{i2} * \hat{\pi}_{i3} * ... * \hat{\pi}_{it}, \tag{4}$$

where

$$\hat{\pi}_{it} \equiv P(ANSWER_{it} = 1 \mid z_{it}, ANSWER_{it-1} = 1). \tag{5}$$

In other words, we estimate multinomial probit models at each time t, including variables observed for all units in the sample at t-1.

To correct our estimates for attrition bias, we finally weight our objective function by $1/\hat{P}_{it}$. All in all, this procedure only marginally affects the estimation results. The impact of financial constraints is in the models with and without correction for attrition bias statistically significant.

Testing for endogeneity

A further potential problem is endogeneity. Endogeneity would imply inconsistent estimations. Since there is a lag between dependent and independent variables, at least the problem of reverse causality should be reduced in our models. With respect to our financial variables reverse causality may be a problem anyway, as it could be argued that external capital owners are able to predict future developments of start-ups. It is, however, not clear how important a firm's quality is to acquire external capital. As a result of asymmetric information and the limited availability of external capital, even firms that have good prospects of success may have problems to acquire external capital. Hence, we would not expect a very high correlation between our measures of financial constraints and firm success. The fact that in our data set, the correlations between dependent variables and financial

[8] Absorbing state means that once a firm drops out of the sample, the firm is out forever.

constraints are in each cross-section bellow 0.2 strengthens this argument (see Table B.6). Endogeneity should thus be of little relevance in our model. This applies all the more as we include the constraint variables in an extensive base model that controls for different aspects of firm quality.

To test for endogeneity we apply the Rivers-Vuong-Test (Wooldridge 2002b, p.483), which tests the null hypothesis that the financial variables are exogenous. In a first stage, we estimate instrument equations for the financial variables separately for each cross-section. All instruments in our instrument equations fulfill the required conditions: they are correlated with the dependent variable in the instrument equation (constraint equation) but not with the dependent variable in the structural equation (success equation) and they are not correlated with the residuals of the endogenized success equation (for details of measurement see Table 3.1). In accordance with Wooldridge (2002b), we further test the over identifying restrictions (Wooldridge 2002b, pp.484–5). All instruments pass this test. In a second stage, we include the residuals of the first stage in our success equations. To correct the standard errors of the estimated parameters we use bootstrapping. Under H_0 the residuals of the instrument equations and the residuals of the second stage equations are uncorrelated.

We test for each cross-section the overall variables DEBT_CONST and VC_CONST.[9] Since the tests of endogeneity and tests of over identifying restrictions are conducted only after unweighted estimations, we test without correcting our estimates for selective attrition. Using our instruments, we cannot reject the null hypothesis of exogenous variables in any case (see Table B.4 and Table B.5). Further estimates with lagged financial variables,[10] as well as the inclusion of past values of BREAK as additional independent variables,[11] confirm

[9] In further estimates not presented here, we tested some of the detailed variables for endogeneity. In all cases, these tests confirmed the test results for the overall variable.

[10] For cross-sections 2003 and 2006 we further conducted a weak test on endogeneity by lagging the financial variables by one period. In general, the additional time lag did not change the impact of the variables on firm success. Despite the large time lag, only the impact of the two variables measuring credit conditions (CRED_COND) and venture capital constraints (VC_CONST) on profit break-even was not significant anymore in cross-section 2003.

[11] External capital constraints measure the need of additional external capital as well as the availability of external capital. The achievement of profit break-even in a certain cross-section may directly affect a firm's financial constraints in the following period, what would implicate a problem with reverse causality. Although the Rivers-Vuong-Test indicates that our results are not affected by endogeneity, we further tested the robustness of our results by including past values of BREAK as additional independent variables in our model. This extension, however, did not affect our main results.

this result. We thus assume that financial constraints affect the success of the start-ups directly and there is no problem with endogeneity.

3.5 Estimation results

Estimation results are reported in Table 3.2 and Table 3.3, respectively. The tables show average marginal effects of the variables and their corresponding standard errors. In both models only a few of the control variables have a statistically significant effect on firm success. In the survival models, the large time lag between dependent and independent variables may partially explain this fact. With respect to financial constraints we find, however, in both models the expected negative impact on firm success, what emphasizes the importance of financial constraints for start-ups. To test the robustness of these results, we alternatively estimated the equations including only variables that had a statistically significant effect in the particular success model. While this strongly increased the model quality, it only marginally affected the estimation results.

The significant results for the control variables are in line with our expectations. The average age of the firm founders (LAGE) seems to capture the retirement effect – the impact of LAGE in each model is negative.[12] While innovation output (NP, MP) in both models is positively correlated with firm success, we find a negative impact of R&D on the profitability. Limited liability (AG, GmbH) has a negative effect on profit, but positively impacts the survival of the firms.

We turn attention now to the main focus of our paper, the impact of financial constraints. In a first step, we analyze for the first cross-section, whether the results confirm the expectations that financial constraints negatively affect success (hypothesis 1).

Success vs. financial constraints

In the survival model, the results for external debt constraints are in line with hypothesis 1. External debt constraints significantly affect firm survival in the first years after firm foundation. Unfavorable credit conditions (CRED_COND), a too low credit line

[12] Further tests with more than one dummy variable showed that the impact of professional experience on success is weak. Only surviving the period 2000-2003 is, up to a certain level, positively affected by an increasing age of the founders.

(CRED_LINE) as well as the overall variable DEBT_CONST have a significant negative impact on the survival of start-ups between the years 2000 and 2003 (see Table 3.2). Only insufficient information about external debt financing options (DEBT_INFO) does not have a significant effect in this period.

Based on English data, Saridakis et al. (2008) find that survival is only affected if firms had serious financial problems. In further estimates, we thus analyze the threshold for the effect of external debt constraints on success by using dummy variables (see Table 3.4). As in the paper of Saridakis et al. (2008), we find that the impact on survival is only statistically significant if external debt constraints are of high importance (value 4 or 5 on respective five-level Likert scale). A shift from a firm that has no external debt constraints to a firm that is highly constrained is correlated with a decrease of the survival probability of about 5%.[13] Interestingly, the effects of credit cost (CRED_COND) and credit rationing (CRED_LINE) on survival are quite similar.

The results for venture capital constraints do not corroborate hypothesis 1. Venture capital constraints (VC_CONST) do not affect firm survival, not even the survival of firms with R&D activities.[14] This is surprising, since innovative firms tend to have more problems to acquire external debt capital and should thus be more dependent on the availability of venture capital. An explanation for this insignificant effect could be that, as Switzerland is short of venture capital for start-ups (see OECD 2008), most founders do not expect to get venture capital funding after firm foundation. The low availability of venture capital may thus discourage firms to enter the market, but does not affect firm survival afterwards.

In the break-even models, the results for external debt constraints as well as the results for venture capital constraints confirm hypothesis 1. External debt constrained firms have more problems to achieve profit break-even. As in the survival models, we cannot find different effects for different dimensions of external debt constraints. All measures of external debt constraints have a significant negative impact on profit (see Table 3.3).

[13] As we use ordinal variables to measure financial constraints, it is not possible to directly interpret the marginal effect of the estimates of Table 3.2 and Table 3.3.

[14] This was tested in further estimates not presented here by including an interaction term between VC_CONST and R&D.

Compared with firm survival, we identify a lower threshold for the effect of external debt constraints on the achievement of profit break-even (see Table 3.4). While firm survival is not affected by low external debt constraints (value 2 or 3 on respective five-level Likert scale), they negatively impact the profits. A shift from a firm that has no external debt constraints to a firm with low constraints decreases the probability to achieve profit break-even by about 8%. The negative impact is significantly larger for higher constrained firms. Serious financial constraints (value 4 or 5 on respective Likert scale) decrease the probability to achieve profit break-even by about 10%.

Venture capital constraints are also negatively correlated with the probability to achieve profit break-even. However, the threshold is higher than that for external debt constraints. Only serious venture capital constraints (value 4 or 5 on respective Likert scale) significantly affect the probability to achieve profit break-even. On this level, the impact of financial constraints on the probability to achieve profit break-even is quite similar for external debt capital and venture capital (marginal effect of about -10%).

Table 3.2: Estimates of the survival of start-ups (average marginal effects of probit estimates)

Period	SURVIVING 2000-2003					SURVIVING 2003-2006				
Explanatory variables	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
MAIN	0.063***	0.063**	0.063***	0.062**	0.061**	-0.003	-0.002	-0.002	-0.005	-0.003
	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)	(0.026)	(0.026)	(0.026)	(0.025)	(0.026)
UNEMPLOY	0.036	0.034	0.035	0.035	0.034	0.001	-0.000	-0.000	0.001	0.000
	(0.029)	(0.029)	(0.029)	(0.029)	(0.030)	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)
LAGE	0.028	0.028	0.033	0.032	0.039	-0.111**	-0.111**	-0.112**	-0.114**	-0.113**
	(0.046)	(0.046)	(0.045)	(0.045)	(0.045)	(0.048)	(0.048)	(0.048)	(0.047)	(0.048)
GENDER	-0.030	-0.031	-0.030	-0.032	-0.032	0.002	0.002	0.002	0.003	0.002
	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)
QUAL	-0.006	-0.005	-0.005	-0.005	-0.002	0.014	0.015	0.015	0.015	0.016
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.022)	(0.022)	(0.022)	(0.021)	(0.021)
R&D	-0.011	-0.013	-0.012	-0.012	-0.013	-0.007	-0.008	-0.009	-0.005	-0.009
	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)	(0.027)	(0.026)	(0.026)	(0.027)	(0.026)
NP	-0.014	-0.014	-0.016	-0.016	-0.018	-0.007	-0.008	-0.007	-0.008	-0.007
	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)
MP	0.040*	0.040*	0.039*	0.039*	0.038*	0.007	0.006	0.006	0.007	0.006
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
PCOMP	-0.014	-0.014	-0.015	-0.016	-0.017	-0.015	-0.016	-0.016	-0.015	-0.017
	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.018)	(0.018)
NPCOMP	-0.013	-0.013	-0.013	-0.012	-0.013	-0.010	-0.010	-0.010	-0.010	-0.010
	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)
LCAP	0.010**	0.010**	0.010**	0.010**	0.010**	-0.000	-0.000	-0.001	-0.000	-0.001
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
AG	0.020	0.020	0.019	0.018	0.018	0.036	0.036	0.036	0.035	0.036
	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)	(0.030)	(0.030)	(0.030)	(0.030)	(0.030)
GmbH	-0.001	0.000	-0.001	-0.002	-0.003	0.062**	0.062**	0.062**	0.064**	0.062**
	(0.024)	(0.024)	(0.024)	(0.023)	(0.024)	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)
OTHER	0.015	0.015	0.015	0.016	0.015	0.047	0.048	0.047	0.049	0.049
	(0.034)	(0.033)	(0.034)	(0.034)	(0.034)	(0.049)	(0.050)	(0.050)	(0.049)	(0.050)
LSIZE	0.017	0.017	0.018	0.016	0.016	0.069***	0.069***	0.069***	0.068***	0.068***
	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)
IND_1	0.041	0.040	0.041	0.041	0.041	-0.069	-0.069	-0.069	-0.075	-0.070
	(0.046)	(0.046)	(0.046)	(0.046)	(0.046)	(0.049)	(0.049)	(0.049)	(0.049)	(0.049)
IND_2	-0.010	-0.012	-0.010	-0.007	-0.006	-0.030	-0.028	-0.029	-0.035	-0.029
	(0.035)	(0.035)	(0.035)	(0.035)	(0.035)	(0.041)	(0.042)	(0.042)	(0.041)	(0.042)
IND_3	0.031	0.030	0.029	0.031	0.031	-0.071*	-0.071*	-0.072*	-0.074*	-0.072*
	(0.035)	(0.035)	(0.035)	(0.035)	(0.035)	(0.041)	(0.041)	(0.041)	(0.040)	(0.041)
DEBT_CONST	-0.007**					-0.004				
	(0.004)					(0.004)				
CRED_COND		-0.014**					-0.003			
		(0.006)					(0.007)			
CRED_LINE			-0.011*					-0.003		
			(0.006)					(0.007)		
DEBT_INFO				-0.011					-0.013	
				(0.007)					(0.008)	
VC_CONST					-0.006					-0.003
					(0.008)					(0.008)
N	1589	1589	1589	1589	1589	911	911	911	911	911
McFadden's R^2	0.023	0.023	0.022	0.022	0.020	0.075	0.073	0.073	0.078	0.073
Wald chi^2	32.98**	33.21**	32.17**	31.48**	29.83*	41.24***	40.07***	40.15***	41.22***	39.39***

Notes: See Table 3.1 for the variable definitions; heteroskedasticity-robust standard errors (Huber-White sandwich estimator) are in brackets under the coefficients; ***, **, * denotes statistical significance at the 1%, 5% and 10% test level, respectively.

Table 3.3: Estimates of the profit break-even of start-ups (average marginal effects of weighted probit estimates)

Period	BREAK 2000					BREAK 2003					BREAK 2006				
Explanatory variables	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
MAIN	0.111***	0.109***	0.112***	0.108***	0.104***	0.079**	0.083**	0.080**	0.077**	0.076**	-0.036	-0.033	-0.040	-0.039	-0.047
	(0.029)	(0.029)	(0.029)	(0.029)	(0.029)	(0.038)	(0.038)	(0.038)	(0.038)	(0.038)	(0.047)	(0.048)	(0.047)	(0.048)	(0.048)
UNEMPLOY	-0.035	-0.041	-0.036	-0.038	-0.037	-0.028	-0.030	-0.029	-0.031	-0.028	-0.007	-0.008	-0.011	-0.015	-0.028
	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)	(0.041)	(0.041)	(0.041)	(0.042)	(0.041)	(0.046)	(0.046)	(0.045)	(0.046)	(0.045)
LAGE	-0.004	0.003	0.006	0.010	0.021	0.025	0.024	0.026	0.026	0.025	-0.150*	-0.142*	-0.145*	-0.144*	-0.130*
	(0.053)	(0.053)	(0.053)	(0.053)	(0.053)	(0.065)	(0.065)	(0.065)	(0.065)	(0.066)	(0.076)	(0.076)	(0.076)	(0.075)	(0.075)
GENDER	0.014	0.014	0.016	0.011	0.009	0.047	0.046	0.046	0.047	0.048	0.035	0.033	0.034	0.036	0.029
	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)	(0.033)	(0.034)	(0.033)	(0.034)	(0.033)	(0.036)	(0.036)	(0.036)	(0.037)	(0.037)
QUAL	0.028	0.030	0.028	0.031	0.038	0.037	0.040	0.036	0.039	0.044	0.008	0.005	0.005	0.015	0.012
	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)
R&D	-0.023	-0.028	-0.024	-0.025	-0.020	-0.083**	-0.085**	-0.089**	-0.081**	-0.085**	-0.083*	-0.090**	-0.085*	-0.085*	-0.094**
	(0.030)	(0.030)	(0.030)	(0.030)	(0.031)	(0.037)	(0.037)	(0.037)	(0.037)	(0.037)	(0.044)	(0.044)	(0.044)	(0.045)	(0.044)
NP	-0.034	-0.034	-0.035	-0.038	-0.039	0.136***	0.135***	0.138***	0.134***	0.136***	0.003	-0.001	-0.004	0.004	-0.002
	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)	(0.049)	(0.049)	(0.049)	(0.049)	(0.049)	(0.049)	(0.049)	(0.048)	(0.050)	(0.049)
MP	0.029	0.027	0.029	0.028	0.026	0.044	0.042	0.045	0.043	0.043	-0.006	-0.005	-0.009	-0.007	-0.007
	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)	(0.030)	(0.030)	(0.030)	(0.030)	(0.030)	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)
PCOMP	-0.007	-0.008	-0.006	-0.012	-0.008	-0.006	-0.009	-0.007	-0.007	-0.013	-0.013	-0.003	-0.013	-0.019	-0.009
	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)
NPCOMP	0.016	0.017	0.015	0.018	0.016	0.062**	0.063**	0.063**	0.060**	0.063**	0.123***	0.120***	0.128***	0.120***	0.120***
	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)	(0.031)	(0.031)	(0.031)	(0.032)	(0.032)
LCAP	-0.004	-0.004	-0.003	-0.005	-0.004	0.003	0.003	0.002	0.002	0.002	0.000	0.001	0.001	0.000	0.003
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.009)
AG	0.034	0.034	0.035	0.028	0.028	-0.117***	-0.114***	-0.115***	-0.119***	-0.111**	-0.072	-0.065	-0.075	-0.070	-0.065
	(0.037)	(0.037)	(0.037)	(0.037)	(0.037)	(0.044)	(0.044)	(0.044)	(0.044)	(0.044)	(0.051)	(0.051)	(0.051)	(0.051)	(0.052)
GmbH	-0.056**	-0.054*	-0.057**	-0.061**	-0.060**	-0.080**	-0.081**	-0.082**	-0.079**	-0.079**	-0.028	-0.031	-0.034	-0.028	-0.039
	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)	(0.033)	(0.033)	(0.033)	(0.034)	(0.033)	(0.038)	(0.037)	(0.037)	(0.038)	(0.037)
OTHER	-0.003	-0.004	-0.002	-0.003	-0.005	-0.039	-0.034	-0.041	-0.034	-0.028	0.034	0.029	0.024	0.035	0.028
	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)	(0.075)	(0.076)	(0.076)	(0.076)	(0.076)	(0.085)	(0.085)	(0.084)	(0.085)	(0.080)
LSIZE	0.047	0.043	0.047	0.046	0.044	-0.004	-0.006	-0.004	-0.005	-0.006	0.021	0.021	0.021	0.019	0.021
	(0.038)	(0.037)	(0.038)	(0.037)	(0.037)	(0.029)	(0.029)	(0.029)	(0.029)	(0.029)	(0.030)	(0.030)	(0.030)	(0.030)	(0.030)
IND_1	-0.128**	-0.133**	-0.128**	-0.129**	-0.124**	-0.053	-0.047	-0.048	-0.068	-0.052	0.053	0.060	0.066	0.046	0.059
	(0.053)	(0.053)	(0.052)	(0.053)	(0.053)	(0.067)	(0.067)	(0.067)	(0.067)	(0.067)	(0.074)	(0.075)	(0.075)	(0.074)	(0.075)
IND_2	0.055	0.052	0.055	0.063	0.069	-0.025	-0.020	-0.021	-0.033	-0.023	0.007	0.009	0.018	0.010	0.023
	(0.044)	(0.044)	(0.044)	(0.044)	(0.044)	(0.053)	(0.053)	(0.053)	(0.054)	(0.054)	(0.057)	(0.058)	(0.057)	(0.057)	(0.057)
IND_3	-0.105**	-0.109**	-0.108**	-0.104**	-0.100**	-0.001	0.002	-0.001	-0.013	-0.006	-0.025	-0.020	-0.020	-0.032	-0.026
	(0.042)	(0.042)	(0.042)	(0.043)	(0.043)	(0.052)	(0.053)	(0.052)	(0.052)	(0.053)	(0.057)	(0.057)	(0.057)	(0.057)	(0.057)
DEBT_CONST	-0.020***					-0.015***					-0.020***				
	(0.004)					(0.005)					(0.006)				
CRED_COND		-0.031***					-0.022**					-0.037***			
		(0.007)					(0.010)					(0.010)			
CRED_LINE			-0.033***					-0.026**					-0.038***		
			(0.007)					(0.010)					(0.011)		
DEBT_INFO				-0.028***					-0.029**					-0.040***	
				(0.009)					(0.012)					(0.014)	
VC_CONST					-0.030***					-0.028**					-0.029**
					(0.010)					(0.012)					(0.015)
N	1589	1589	1589	1589	1589	911	911	911	911	911	615	615	615	615	615
McFadden's R^2	0.072	0.069	0.071	0.066	0.065	0.050	0.047	0.049	0.049	0.047	0.081	0.079	0.078	0.070	0.063
Wald chi^2	122.13***	118.96***	121.09***	112.79***	113.31***	47.35***	44.65***	46.12***	43.70***	44.14***	36.71***	36.83***	36.05**	31.73**	29.63*

Notes: See Table 3.1 for the variable definitions; heteroskedasticity-robust standard errors (Huber-White sandwich estimator) are in brackets under the coefficients; ***, **, * denotes statistical significance at the 1%, 5% and 10% test level, respectively.

Table 3.4: Analyzing the threshold for the effect of financial constraints (average marginal effects)

	Probit estimates								Weighted probit estimates											
Period	SURVIVING 2000-2003				SURVIVING 2003-2006				BREAK 2000				BREAK 2003				BREAK 2006			
Explanatory variables	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
(…)																				
LOW_CRED_COND	-0.024 (0.027)				0.013 (0.023)				-0.091*** (0.031)				-0.085*** (0.033)				-0.081* (0.043)			
HIGH_CRED_COND	-0.058** (0.023)				-0.015 (0.025)				-0.104*** (0.027)				-0.086** (0.037)				-0.128*** (0.039)			
LOW_CRED_LINE		-0.033 (0.026)				0.014 (0.023)				-0.082*** (0.031)				-0.074** (0.032)				-0.084* (0.045)		
HIGH_CRED_LINE		-0.045* (0.024)				-0.001 (0.027)				-0.111*** (0.028)				-0.095** (0.038)				-0.123*** (0.040)		
LOW_DEBT_INFO			0.033 (0.028)				0.004 (0.022)				-0.068** (0.031)				-0.023 (0.033)				-0.081** (0.040)	
HIGH_DEBT_INFO			-0.062** (0.027)				-0.062** (0.029)				-0.095*** (0.033)				-0.131*** (0.045)				-0.112** (0.053)	
LOW_VC_CONST				0.035 (0.029)				-0.013 (0.025)				-0.043 (0.034)				-0.044 (0.038)				-0.070 (0.048)
HIGH_VC_CONST				-0.036 (0.031)				-0.008 (0.032)				-0.109*** (0.037)				-0.096** (0.047)				-0.095 (0.058)
N	1589	1589	1589	1589	911	911	911	911	1589	1589	1589	1589	911	911	911	911	615	615	615	615
McFadden's R^2	0.024	0.023	0.025	0.022	0.075	0.074	0.082	0.074	0.070	0.070	0.066	0.065	0.051	0.051	0.051	0.047	0.078	0.075	0.068	0.064
Wald chi^2	34.70**	33.52**	36.31**	32.20**	41.40***	39.85***	45.23***	40.18***	117.84***	118.48***	112.89***	112.03***	49.94***	49.78***	45.33***	43.97***	35.83**	35.89**	31.61**	29.48*

Notes: In these estimations, we include for each ordinal measure of financial constraints two binary variables (low constraints: levels 2 and 3 of the original five-level variable; high constraints: levels 4 and 5 of the original variable; reference: no constraints (level 1 of original variable)); as DEBT_CONST is calculated as the sum of standardized values, it is not possible to directly interpret the coefficients of this variable; we include the whole base model as control variables (see Table 3.2 or Table 3.3); heteroskedasticity-robust standard errors (Huber-White sandwich estimator) are in brackets under the coefficients; ***, **, * denotes statistical significance at the 1%, 5% and 10% test level, respectively.

Persistence of the impact of financial constraints

In a second step, we analyze whether the impact of financial constraints decreases with increasing age of the firms (hypothesis 2). The results of the survival model confirm hypothesis 2. The negative effect of external debt constraints on firm survival disappears with increasing age of the firms. External debt constraints do not affect surviving the years 2003–2006. Further, the impact of venture capital constraints on firm survival remains statistically insignificant.

One reason that the impact of financial constraints gets insignificant in the second period may be that firms with high financial constraints already dropped out in the previous period. In further estimates we thus analyzed the impact of persistent financial constraints by including only firms that were highly constrained (value 4 or 5 on respective Likert scale) in the period 1996/97–2000. We found that in the second period (2000–2003), financial constraints do not even impact survival of firms which were strongly constrained in the previous period (1996/97–2000).

Rather unexpected, we find no supportive evidence for hypothesis 2 in the break-even models. In all three cross-sections, the negative impact of external debt constraints and venture capital constraints on profit remains significant. Furthermore, also marginal effects remain quite similar in magnitude. As most firms stayed small over time, a possible explanation for this persistent effect is that it remained difficult for the firms to gain access to external capital.[15] Information collection of small firms relative to the loan size is more costly. External capital owners will thus hesitate to lend money to small firms. Since even the biggest firms in our sample remained quite small, it is hardly possible to test this explanation. It is thus no surprise that we found no significantly different effects for smaller firms when DEBT_CONST was interacted with firm size. A second explanation for the persistent effect may be that some years after firm foundation internal financial flows of the firms are still limited. While in 2000 27 percent of the firms reported that they had not enough internal

[15] In 2006, the firms in our sample had on average a size of 4.8 employees and only 2% of the firms had more than 20 employees.

capital, the share decreased to 19 percent in 2006. Accordingly, dependence on external capital remained large.

Our analysis of hypothesis 2 is based on the assumption that each cross-section reflects a further stage in the development of the start-ups. However, as the surrounding environment also changes over time (time effect), it is not a priori clear whether different effects between different cross-sections are driven by increasing age of the firms (age effect). The most important factors to describe time effects are probably business fluctuations. The availability of external capital should be positively correlated with the business cycle. In Switzerland, 1996–2000 and 2003–2006 were periods of economic growth, while 2000–2003 were years of relative stagnation. If in our model time effects would dominate age effects, the impact of financial constraints should remain significant in the second period, but should disappear in the third period. The estimation results, however, show that the impact of financial constraints on firm survival disappears in the period 2000–2003. Further, despite economic growth in the period 2003–2006, the impact of financial constraints on profit remains significant. We thus conclude that the different effects between cross-sections are driven by increasing age of the firms and not by changes in the surrounding environment.

Differences between the two dependent variables

A comparison of the results across the two dependent variables confirms that firm survival is a more fundamental measure of success than the achievement of profit break-even. Firstly, we find a lower threshold for the effect of financial constraints on profit than on survival, and the marginal effects are also larger in magnitude in the profit models. Secondly, while the impact of financial constraints on survival disappears with increasing firm age, the effect on profit remains statistically significant. Surprisingly, we find no evidence for hypothesis 2 in the profit break-even model. The impact of financial constraints on profit neither disappears nor decreases with increasing age of the firms.

3.6 Conclusions

Given the economic importance of start-ups and the intense interest by policymakers to encourage entrepreneurship, it is important to understand the link between financial constraints and success of these firms. In this study we do not only analyze whether the

success of start-ups is affected by financial constraints, but also whether the success of start-ups is still affected when these firms grow older.

The estimation results show that firm survival and the achievement of profit break-even are negatively correlated with financial constraints. Only the impact of venture capital constraints on firm survival is not statistically significant. With increasing firm age, the impact of financial constraints on the survival probability disappears. The negative effect on the probability to achieve profit break-even, however, remains statistically significant. Ten years after firm foundation, financially constrained firms still have more problems to achieve profit break-even. Furthermore, we cannot even observe a decreasing impact of financial constraints on profit when the firms grow older. We thus conclude that, at least in the medium term, success of start-ups is persistently affected by financial constraints. Accordingly, public support for the start-ups in the initial stage cannot solve the problem of financial constraints. Instead, financial market imperfections should be further reduced to permanently improve access to external capital.

4 What Determines the Innovation Capability of Firm Founders?*

4.1 Introduction

Most start-ups have more in common with self-employment than with the creation of high-growth companies (Shane 2009, p. 142). Along with Shane (2009), several recent papers thus conclude that simply encouraging more people to become entrepreneurs is not necessarily the best policy for enhancing economic growth (see, e.g., Bosma et al. 2011, Canter & Kösters 2009, Fritsch & Schroeter 2009). Hence, especially for policy makers it is important to be able to identify firms with a high probability of growth perspectives. Starting point of our analysis is the idea that an important characteristic of such high-growth firms is their innovation performance. Innovative start-ups are considered to be important drivers of innovation in existing industries (Aghion et al. 2006, Schumpeter 1934) and should also positively affect the creation of new industries (Acs & Audretsch 1990). Despite this expected positive impact on economic growth, relatively little is known about the factors that determine the innovation performance of start-ups.

The innovative activity of start-ups might strongly depend on the characteristics of the firm founders, e.g., educational background and experience. The founders determine a firm's strategies and coordinate the resources to implement them (Barringer et al. 2004, Bergmann Lichtenstein & Brush 2001). Further, as start-ups are mostly small firms, the capabilities of the founders themselves serve as important resources to create a competitive advantage (Hadjimanolis 2000). Founders do not only decide whether to innovate or not, but are directly involved in the innovation process of the start-ups. Knowing the innovation capability of firm founders would make it much easier to identify the innovative start-ups, especially as most of these characteristics are easy to observe and remain constant over time.

While there is empirical evidence for such a link between management characteristics and innovation activities for established firms (see, e.g., Barker & Mueller 2002, Chen et al. 2008, Hadjimanolis 2000, Romijn & Albaladejo 2002), to our knowledge only two studies deal with the relationship between founder characteristics and innovation using data of newly-founded

* This chapter is based on Arvanitis & Stucki (2010).

firms. The first one is the study of Lynskey (2004) that analyze the impact of the CEO characteristics based on Japanese firm-level data that were collected in 1999 and refer to technology-based firms that were founded 10 years or less before the survey, i.e. at the earliest in 1989. In a second study Koch & Strotmann (2008) analyze the impact of founder characteristics on the innovation performance of German start-ups in the knowledge-intensive business sector. In both studies, managerial characteristics and founder characteristics, respectively, showed rather low explanatory power.

Our study contributes several new elements to existing empirical literature. First, our empirical basis is a sample of start-ups that is representative of all firms founded in 1996/97 in Switzerland as recorded by a census of the Swiss Federal Statistical Office for this period. Further, while previous studies are based on data for one cross-section, we dispose of data for three cross-sections, so that we can follow the development of the start-ups over a period of almost ten years. This allows us to analyze at the same time the existence and the persistence of innovation activities. Furthermore, we can also investigate the effects of changes of the composition of the founding teams on innovation. Another important feature of our study is the wide spectrum of variables, especially with respect to founder characteristics, that could be taken into account in the model specification. In previous studies, the available founder information is limited and not really representative for the whole founding team.

As already mentioned in this paper we investigate the influence of founder characteristics on the innovative activity of start-ups based on Swiss data for the start-up cohort 1996/97. We find that the founders' education level, the level of their experience in R&D and the availability of innovation-relevant ideas coming from the founder persons are the main characteristics that enhance innovation activities of start-ups. We also find mutually reinforcing effects of these most important founder characteristics. At the maximum, combinations of these three factors within a founding team can increase the probability of innovative activities by about 40%.

The remainder of the paper is organized as follows: Section 4.2 presents the conceptual background of the empirical analysis and derives our main hypotheses. Section 4.3 describes the database. Section 4.4 discusses the methodology of our analysis. Section 4.5 presents the

estimation results. Section 4.6 contains a comparison with results of similar studies. Section 4.7 concludes our paper.

4.2 Conceptual background and hypotheses

Our conceptual framework builds upon the resource-based approach of the firm, according to which a direct link is assumed between a firm's competitive advantage and the individual resources of the employees, especially with respect to managing persons (see Barney 1991). Thus, the performance of start-ups should be strongly related to their innovation capability as reflected by the individual resources and capabilities of the founding persons (see, e.g., Capaldo et al. 2003, Hadjimanolis 2000 and Romijn & Albaladejo 2002 for a similar approach). As most start-ups are small firms, firm founders are directly involved in the operational process of the firms. Founders also make strategic decisions such as the choice to innovate or not. Knowledge and skills of entrepreneurs are thus important resources of the start-ups and should also impact innovative activity. In this paper we analyze the relationship between innovative activity of start-ups and founder characteristics, embedded in an extensive model of determinants of innovation.

In view of the complexity of the innovation process characterized by several stages from basic research to the penetration of the market with new products, an approach relying on a single measure of innovation may leave out important relationships and produce results that are not robust (see, e.g., Kleinknecht et al. 2002, Rogers 1998). In this study we use two innovation measures covering the input as well as the output side of the innovation process. In our model, innovation output is measured by the introduction of new or modified products (IP). The existence of R&D activities (R&D) indicates innovation input. Following the theoretical literature and in accordance with empirical studies, our model includes three categories of independent variables: founder characteristics, firm characteristics and characteristics of a firm's environment.

4.2.1 Founder characteristics

As we primarily focus on the impact of the founder characteristics on the innovative activity, we include an extensive set of variables which may impact the innovation capability of the firm founders. Firms in our sample may be founded by a group of founders or by a single

founder. Variables describing the characteristic of the firm founders thus refer to the characteristics of the whole founding team, independent of whether the firm was founded by a team with more than one founder or by a single founder.

Theoretical literature on entrepreneurship either deals with single entrepreneurs (see Lazear 2005) or with team foundations (see Fabel 2004). Empirically, however, there may be significant differences between solo and team start-ups. *Team foundations* combine people with diverse personalities, characteristics, knowledge, skills and abilities. Such combinations should positively stimulate the performance of the firms (see Lechler 2001, Thakur 1999). Furthermore, the number of external network relationships and the availability of resources should be positively correlated with team foundations (see Brüderl et al. 2007), also indicating a positive impact on innovative activities. On the other hand, heterogeneity increases the risk of problems and conflicts within the founding team (see Brüderl et al. 2007, Stam & Schutjens 2006). In line with the findings of most previous empirical studies on the economic performance of start-ups, we expect, however, that the positive effects of team foundations outweigh the negative ones.

H1: Innovation propensity should be higher in firms with team foundations than in firms with single founders.

The human capital of the founding team, especially the education level of the founders, should be an important factor for innovation. Through formal education, people acquire skills which help to recognize business opportunities in the surrounding environment (Shane 2000). Further, a higher level of education may increase the ability to absorb new ideas, thus the ability to identify innovative opportunities (Barker & Mueller 2002, p.787). This is the rationale of the competence-based view according to which founders with great human capital would outperform founders with less human capital (see Colombo & Grilli 2005 for the development of this argument). Furthermore, it is more likely that founders with a high education would dispose of more wealth than persons without a high education. Thus, they would also have access to more capital to finance firm's operations. In this case economic access may be traced back primarily to better internal and external financing opportunities (wealth-based view; see, e.g., Åstebro & Bernhardt 2005) and the wealth effect would explain the positive effect of human capital (see Colombo & Grilli 2005). In this study we correlate

human capital directly with innovation, so we have the possibility to test the competence-based view.

H2: We thus expect that firms with a founding team with a high level of education would show a higher propensity to innovation than firms with a founding team with a lower level of education.

Not only the level of education, but also the *type* of education of the founders may impact innovation. Commercial education primarily enhances accounting and marketing capabilities. In contrast, people with a technical education background may have a more complete understanding of technology and innovation (Barker & Mueller 2002, p.787; Hambrick & Mason 1984, p.201).

H3: These arguments suggest that firms with founding teams with pronounced technical know-how would tend to have more innovative activities than firms with founding teams with primarily commercial education.

Besides formal education, prior *industry experience* also affects considerably the ability to detect (innovative) opportunities (Colombo & Grill 2005, Shane 2000). As new firms have no track record, such experience is of special importance. In order to be able to identify opportunities for new products and services, it is important for a firm founder to be familiar with customer needs and market developments.

H4: We thus expect that founding teams with prior industry experience would tend to initiate more innovative activities than founding teams without or little prior industry experience.

Previous self-employment experience indicates the accumulation of business skills. Experience gained in previous self-employment episodes is a preparation for the entrepreneurial role (Brüderl et al. 1992, p. 229; see also Colombo & Grilli 2005). Starting a new business requires specific management know-how, for example with respect to finances or organization of production or marketing. Prior experience as self-employed reduces costs to manage “basic” tasks, thus allowing firm founders to concentrate on other tasks such as innovation activities.

H5: We expect that founding teams with self-employment experience have more innovative activities than founding teams without self-employment experience.

Innovative activities imply a certain level of innovation-specific know-how. This type of knowledge is needed to assess the potential of competing research streams, to develop R&D strategies or to organize and coordinate research projects (see Barker & Mueller 2002, Lynskey 2004).

H6: Founding teams with R&D experience have more innovative activities than founding teams without such experience.

Besides specific innovation know-how in technical terms, innovative activities often build upon concrete ideas about possible innovative projects based on experience made in earlier occupations of the founders either in research or in business. The realization of such innovation-relevant ideas is often an important motivation for starting a new business. The decision whether a firm has innovative activities should thus also depend on the availability of such *innovation-relevant ideas.*

H7: In firms which were founded to implement concrete ideas from a founder's former occupation, innovation-relevant ideas seem to be available. Therefore, we would expect that these firms have more innovation activities.

The hypotheses H6 and H7 refer to core capabilities for innovation and build in a certain sense the nucleus of our investigation. The idea is that even if formal education and previous industry and management experience are often necessary pre-conditions they may not be sufficient for innovation. "The idiosyncratic, non-contractible nature of entrepreneurial judgment when an individual identifies a new and hitherto unrecognized business opportunity" as Colombo & Grilli (2005, p. 80) put it, is presumably a crucial characteristic of innovative founders (see also Foss 1993).

Investment in innovation is a long-term investment and pay-offs are uncertain at the time of investment. Innovative activities would thus be related to the risk behavior of the founding team. An important proxy for this behavior is the *age* of firm founders. As older firm founders have a shorter investment horizon and are more inclined to secure primarily their retirement income, they would tend to be more risk-averse than younger founders (see Hambrick & Mason 1984, p. 198). Risk-taking is also influenced by *gender*. Women typically are more likely to be risk-averse (see, e.g., Eckel & Grossman 2002, Jianakopolos & Bernasek 1998).

So we include in our model specification also controls for the average age as well as for the gender of the majority of the founding team.

4.2.2 Firm characteristics

As most start-ups are small firms, it is difficult to separate the effect of the founding team and the effect of the other employees of the start-ups. Thus, we refrain from including in addition to the variables describing the founder characteristics also variables measuring the human resources of the other employees. We control for such resources by inserting a variable for *firm size*. Larger firms are expected to have more resources for innovation projects than smaller ones. Firm size should thus positively impact innovation activities.

Competing on the international market requires competitive advantages. The *export* orientation of a firm would thus be positively correlated with its innovative activity (see Roper & Love 2002). Since diversified firms have more opportunities to use new knowledge, *product diversification* would enhance innovative activities of these firms (see Katila 2002, p.1002).[1]

4.2.3 Market conditions

We expect that positive *demand expectations* would positively stimulate present innovation activities (see Horbach 2007).

Internal resources of start-ups are limited. External networks can provide additional knowledge and expertise (Malerba & Torrisi 1992, Shan et al. 1994). *Cooperation* with other firms or institutes, especially cooperation in R&D, would increase the amount of available knowledge and thus positively impact innovative activities. Furthermore, as start-ups are often financially constrained, innovation activities may be stimulated by public financial support. In our sample, however, less than 5 percent of the firms received public subsidies and for only 1 percent of the firms this financial support was of high importance. So we refrain from inserting a variable for public support in our model.

Markets with intensive *competition* require greater flexibility and would in general force firms to become more innovative (Katila & Shane 2005). However, as experience and

[1] Diversification would make it more difficult for the management to monitor the firm's R&D activities. In large firms, this may lead to decreasing commitment to innovation activities, but this is of limited relevance for the small start-ups in our sample.

resources of start-ups in general are limited, intensive *price* competition may discourage innovation, intensive *non-price* competition encourage it. Finally, to capture industry specific effects, we further include dummies controlling for *sector affiliation*. To capture different effects for modern services and traditional services, respectively, we include a separate dummy for each of the two sub-sectors.[2]

4.3 Description of the data

The sample we use in this study is based on the cohort of Swiss enterprises that were founded between 1996 and 1997 and recorded by the Swiss Federal Statistical Office. This cohort contained 7112 "green-field" start-ups (i.e. mergers and manager-takeovers were not included) that were founded in this period and were active (i.e. conducted business activities at least twenty hours a week).[3] For this sample only the firm size, the industry affiliation and the region of the firms' location were known. 3288 of these start-ups were still in business in 2000 (survival rate 2000: 46.2%).[4] Among these firms data were collected by means of a postal survey. 1625 of them firms answered the questionnaire (response rate 2000: 49.2%). 1339 of these firms survived the next three years (survival rate 2003: 82.4%). In 2003 a follow-up survey was conducted among these firms. Answers were received from 945 of the firms (response rate 2003: 70.6%). In 2006, three years after the second survey and nine to ten years after the firm's foundation, 857 of the participants of the 2003 survey still existed (survival rate 2006: 90.7%). 630 of them were willing to fill out a third questionnaire (response rate 2006: 73.6%). For some firms we thus have data at different points in time. For firms which dropped out of the sample we know whether the firm still existed at the time of drop out and also whether the firm survived the following period up to 2006. In sum, the data set covers 3200 observations. Because of missing values for single variables only 2393 observations could be used for econometric estimations.

Most of the start-ups in the data set are firms in the service sector. In each point of time they represent about 83% of the observations. About 9% belong to the construction sector, the

[2] As less than 10% of the firms in our sample belong to the manufacturing sector, it was not possible to make such a distinction for the manufacturing sector.
[3] The firms were recorded by the Swiss Federal Statistical Office independently whether they were enrolled in the Swiss Commercial Register or not.
[4] The current status of the firms was checked to a large part by phone.

remaining 8% to the manufacturing sector. These shares remained almost constant during the period 2000–2006. In the service sector the sub-sector of modern (knowledge-intensive) services (e.g., banking and insurance, business services) has a larger share than the sub-sector of traditional services (e.g., trade, hotels and catering); the share of modern services increased considerably between 2000 and 2006 (about 47% in 2006). In the manufacturing sector there are more low-tech (about 5%) than high-tech start-ups (about 3%).

The observed start-ups are for the most part small firms. In each survey more than 80% of the enterprises employed less than five employees (measured in full-time equivalents). The average firm size only slightly increased from one period to the next. While in 2000 the firms had on average a size of 2.8 employees, the average size increased to 3.6 employees in 2003 and 5.3 employees in 2006. In 2006, ten years since their foundation, only 8.4% of the firms employed more than ten employees.

The questionnaire covered questions about basic firm characteristics, firm performance and activity level, resource endowment, innovative activities and the market environment.[5] In 2000, the questionnaire included detailed questions about the founder characteristics (e.g., gender, age, education, experience) at time of firm foundation. As we have this information for up to three representative firm founders and less than 4% of the firms in our sample have more than three founders, we are able to describe in detail the characteristics of the whole founding team.

4.4 Econometric framework

To capture different aspects of innovative activity we estimate our model using a proxy for innovation input as well as a proxy for innovation output. R&D is a binary variable measuring whether a firm had R&D activities. IP is a binary variable measuring whether a firm introduced new or modified products.

To explain innovative activities we include all variables presented in Section 4.2 (for a detailed definition of the variables and descriptive statistics by cross-section see Table 4.1 and Table C.1, respectively). Models comprise for both innovation variables the same independent

[5] The questionnaire is available in German, French and Italian at www.kof.ethz.ch/surveys/structural/panel.

variables. To take into account the binary character of the dependent variables we estimate probit models.

4.4.1 Sample attrition

Between two subsequent surveys some firms disappeared from the market and some other did not want to participate to our survey anymore. The question is whether the remaining samples are still representative. When determinants of selection are correlated with innovative activities, attrition is selective, and traditional econometrical techniques will lead to biased and inconsistent estimates. Following Wooldridge (2002a, p. 581) we test for selective attrition between two cross-sections by inserting a selection indicator as an additional explanatory variable in our model, running the regression and testing the statistical significance of the coefficient of the selection indicator. As a selection indicator we use the dummy variable INSAMPLE that takes the value one if a firm is still in our sample in the following cross-section and zero if not. We have no such indicator for cross-section 2006, so we can apply this test only for the cross-sections 2000 and 2003. Test results indicate that selective attrition is of minor importance; the coefficient of the selection variable is only in one of eight models statistically significant (at the 5% test-level) (see Table C.2 in the appendix). This result is further supported by cross-section specific descriptive statistics for the founder characteristic variables. Descriptive statistics for these time-invariant variables show that the composition of the data set does not significantly vary between cross-sections (see Table C.1). Thus, pooling the data of the different cross-sections without correcting for selective attrition seems to be an adequate procedure.

Table 4.1: Analyzing combinations of founder characteristics

Variable	Definition/ measurement
Dependent variables	
R&D	R&D activities yes/no (in previous period)
IP	Development and introduction of new/modified existing products yes/no (in previous period)
Independent variables	
LEVEL_UNI, LEVEL_O_TERTIARY	Dummies describing the dominant education level of the firm founders (most founders have a university degree (LEVEL_UNI); most founders have another tertiary-level education (LEVEL_O_TERTIARY); reference group: most founders do not have a tertiary-level education)
TYPE_TECHNICAL, TYPE_COMMERCIAL, TYPE_MIX	Dummies describing the type of strength of the founding team (team has pronounced technical but not management know-how (TYPE_TECHNICAL); team has pronounced management but not technical know-how (TYPE_COMMERCIAL); team has pronounced technical as well as management know-how (TYPE_MIX); reference group: team has not pronounced technical and management know-how; transformation of two five-level ordinal variables (level 1: 'very weak'; level 5: 'very strong') to binary variables (value 1: levels 4 and 5 of the original five-level variable; value 0: levels 1, 2 and 3 of the original variable))
EXP_IND	At least one of the founders has industry experience yes/no
EXP_SELF	At least one of the founders has experience with self employment yes/no
EXP_RAD	At least one of the founders has R&D experience yes/no
INNO_IDEA	Firm was founded to implement concrete ideas from the founders former occupation yes/no (transformation of a five-level ordinal variable (level 1: 'very low importance'; level 5: 'very high importance') to a binary variable (value 1: levels 4 and 5 of the original five-level variable; value 0: levels 1, 2 and 3 of the original variable))
LAGE	Average age of the firm founders; natural logarithm
GENDER	Gender of the firm founders: male/female (value 1: ‘male’; value 0: ‘female’; the most frequently reported gender is regarded as representative for the firm founders; when the number of 'females' equals the number of 'males' we set 'female')
MALE_TEAM, MIXED_TEAM	Dummies describing the gender mix of the founding team (all team members are male (MALE_TEAM); there are males and females in the founding team (MIXED_TEAM); reference group: all team members are female)
TEAM_FOUNDATION	Firm was founded by at least two founders yes/no
LSIZE	Number of employees; natural logarithm
EXPORT	Firm exports goods and/or services yes/no
DIVERSIFICATION	Firm is present in more than one product and/or service sector yes/no
DEMAND_FUTURE	Development of a firm’s specific product demand in the next two years (transformation of a five-level ordinal variable (level 1: ‘strong decrease’; 5; ‘strong increase’) referring to the (reference year: survey year); to a binary variable (value 1: levels 4 and 5; value 0: levels 1, 2 and 3 of the original five-level variable))
COOPERATION	Firm cooperates with other firms/institutes yes/no (dummy variable measures whether or not a firm cooperates in acquisition, production, distribution or R&D)
PCOMP	Intensity of price competition (transformation of a five-level ordinal variable (level 1: 'very weak'; level 5: 'very strong') to a binary variable (value 1: levels 4 and 5 of the original five-level variable; value 0: levels 1, 2 and 3 of the original variable))
NPCOMP	Intensity of non-price competition (original and transformed variables as for PCOMP)
MANUFACT, MOD_SERV, TRAD_SERV	Dummies for three sectors (manufacturing (MANUFACT); modern services (MOD_SERV); traditional services (TRAD_SERV); reference sector: construction)
Y2003, Y2006	Time dummies for the years 2003 and 2006, respectively (reference year: 2000)
INSAMPLE_03	Firm is still in the sample in cross-section 2003 yes/no
INSAMPLE_06	Firm is still in the sample in cross-section 2006 yes/no
INSAMPLE_NEXT_PERIOD	Firm is still in the sample in the next cross-section yes/no

4.4.2 Heterogeneity

Likelihood-ratio tests show that the pooled probit model is not the appropriate estimation method (see the lower part of Table 4.2). Fixed-effects approaches cannot be applied to our data. Our main variables describing the founder characteristics have no variation over time within a firm. Hence, these variables would be wiped out when taking first differences and we would not be able to identify the effects of the founder characteristics (see Raymond et al. 2010 for a detailed discussion on this issue). To deal with unobserved firm heterogeneity through individual effects, we estimate random-effects models where the likelihood functions are calculated by Gauss-Hermite quadratures.

4.4.3 Endogeneity

A further potential problem is the possible endogeneity of some of the right-hand variables that would imply inconsistent estimates. Since the data dealing with the founder characteristics refer to the point of time of the firm foundation and remain constant over time, our main results should at least not be affected by reverse causality. However, endogeneity may still be a problem, as we cannot eliminate the potential problem of initial conditions. The only straightforward way to solve the initial conditions problem – run a fixed effects model – is ruled out because we have no over-time variation in founder characteristics. As a consequence, we refrain from making causal claims. Instead, our estimation results are interpreted as partial correlations.

Finally, as one can see in the correlation matrix in Table C.3 in the appendix, the results are also not driven by multicollinearity.

4.5 Results

4.5.1 Factors influencing the innovation performance of start-ups

General Pattern

The results of the random-effects estimates are reported in Table 4.2. Column (1) and (3) show the estimated coefficients and the corresponding standard errors. Column (2) and (4) show average marginal effects.

Team foundations (TEAM_FOUNDATION) perform better with respect to innovation output, but not with respect to innovation input. Thus, hypothesis H1 is confirmed, at least for innovation output. This result is quite similar to the one for education types (see below). A mix of qualification types as well as a combination of more than one founding individual correlate positively with the introduction of innovative products.

Primarily, we are interested in the influence on innovative activities exerted by the variables describing the specific founder characteristics. As expected, the education level of the firm founders shows a positive correlation with innovation activities of the start-ups. Firms with a majority of founders that have a university degree (LEVEL_UNI) have significantly more innovative activities. A shift from a founding team that predominantly comprises of persons that do not have (academic) university education to a team, in which most members have such education, is correlated with an increase of 11.1% and 9% of the likelihood that the firm introduces innovative products and conducts R&D activities, respectively. Interestingly, we can observe such an effect only for university education. The impact of the variable for tertiary-level education other than academic university education (LEVEL_O_TERTIARY), such as a degree from universities of applied science, is not statistically significant. Thus, hypothesis H2 is confirmed, at least for university education.

The estimates in Table 4.2 corroborate only partly hypothesis H3, namely with respect to R&D activities. For start-ups with a founding team with pronounced technical know-how (TYPE_TECHNICAL) a significantly positive correlation with R&D propensity is found, while for new firms that have founders with primarily commercial know-how (TYPE_COMMERCIAL) the estimates show a negative correlation with R&D propensity. We could not find significant effects of these two variables for the output variable IP. The

founders' technical background might be positively related with R&D activities but is apparently not a necessary precondition for innovation output. Moreover, our results demonstrate that a mix of both qualification types (TYPE_MIX) is required for having R&D activities as well as for being able to introduce innovative products.

Hypothesis H4 is not confirmed as the results for the variable EXP_IND demonstrate. The effect of industry experience on innovation output IP is statistically insignificant, while the effect on R&D activities is significantly negative. A reason for this negative effect may be that teams with industry experience are less inclined to conduct R&D than founders with research background. In our sample less than 3 percent of the firms have at the same time industry experience and R&D experience. However, as industry experience helps people to find market niches, it is not surprising that firms that have founders with industry experience show, despite less R&D activities, not significantly less innovation output.

The coefficient of the variable for self-employment experience (EXP_SELF) is statistically insignificant. The expected positive effect of accumulation of business skills is discernible only in the early years. In estimates of the model separately for each cross-section, we find that in the first period 1996/97–2000 founding teams with self-employment experience have significantly more innovative activities (innovation input as well as innovation output) than other teams. In the later stages, the effect gets insignificant. This is an intuitively plausible result, as particularly in the first period self-employment experience helps to limit costs of administrative tasks and more time is available for innovative activities. With increasing firm age other teams also make such experience, wherefore the advantage disappears. Thus, hypothesis H5 receives only partial confirmation.

The strongest effect on innovative activities as measured by the respective marginal effect is found for the variable that measures R&D experience (EXP_RAD). The availability of such innovation specific know-how increases the probability of innovation input and innovation output by 20.2% and 18.2%, respectively. The coefficient of the variable for concrete innovation-relevant ideas from prior occupations (INNO_IDEA) is also positive and statistically significant. Firms that were founded in order to realize concrete ideas for innovations from the founder's former occupation (either in research or in business) have on average an 8.3% and 10.3% higher probability of innovation input and innovation output,

respectively, than firms without such ideas. Therefore, the hypotheses H6 and H7 are clearly confirmed by our estimates.

In the pooled data set, the effect of the average age of the founders (LAGE) is statistically insignificant. However, as we will see in Section 0, the effect of the risk behavior of the firm founders becomes significant when investment in R&D is persistent; persistent innovation activities are negatively correlated with the average age of the firm founders (see column 4 in Table 4.5).

As expected, we find a positive sign for male founding teams. However, the effect is statistically significant only for R&D activities. Thus, start-ups with only male team members (MALE_TEAM) show a higher propensity to perform R&D than firms with exclusively female members or firms with founding teams that are mixed with respect to gender.

Finally, the results for the other variables are in line with the expectations. Exporting firms (EXPORT), firms with product diversification (DIVERSIFICATION), firms with cooperation (COOPERATION) and firms that expect a positive development of the firm-specific product demand (DEMAND_FUTURE) tend to a higher innovation propensity than firms without such characteristics. While intensive non-price competition (NPCOMP) correlates positively with innovation output, no effect is found for the intensity of price competition (PCOMP).

Not surprisingly, sector affiliation is related to R&D activities. Firms in the manufacturing sector have significantly more R&D activities than firms in other sectors. Further, there is more R&D activity in the service sector than in the construction sector. Contrary to expectation, firm size (LSIZE) does not affect innovative activities. As the observed start-ups are for the most part small firms, little variance in firm size may be the reason for this result.

On the whole, estimation results show that innovative activities of start-ups are strongly related to the characteristics of the firm founders. Innovation capability of the founders is primarily determined by the education level (LEVEL_UNI), R&D experience (EXP_RAD) and the availability of concrete innovation-relevant ideas from earlier occupations (INNO_IDEA).

Mutually reinforcing effects of firm founders' characteristics

The strong impact of the founder characteristics becomes even clearer, when we analyze the effect of combinations of these three variables within a firm. In Table 4.3 we estimated once

more the innovation input and the innovation output model inserting now instead of the original variables for university-level education, R&D experience and the availability of innovation-relevant ideas all six possible combinations of these variables (reference group: firms without any of these characteristics), including the "pure" cases with only one characteristic (combinations: u1_r0_i0 (university-level education); u0_r1_i0 (R&D experience); u0_r0_i1 (innovative ideas) in Table 4.3). Not astonishingly, the "pure" effects are smaller than the "mixed" effects in Table 4.2. At the maximum, combinations of these factors increase the probability of innovation output by more than 40% (combination u0_r1_i1; R&D experience *and* innovative ideas) and the probability of performing R&D by nearly 35% (combination u1_r1_i1; all three characteristics).

For innovation output, all three combinations of two characteristics show marginal effects that are larger than the pure effects of each of the underlying characteristics. In two cases – the combinations "R&D experience/innovative ideas" and "R&D experience/university-level education" – these effects are larger than the sum of the underlying pure effects, thus indicating the existence of mutually reinforcing effects of the respective pairs of characteristics. This is not the case for the combination "university-level education/innovative ideas". Taken as a whole, there is a hint for the existence of complementarity of the underlying pairs of characteristics, R&D experience being a necessary ingredient of the reinforcing combinations. Innovative ideas and university-level education alone are not enough for such a reinforcing effect. This conclusion is further strengthened by the result for the combination of all three characteristics. In this case the marginal effect is smaller than the respective effect for the combination of the two characteristics "university-level education" and "R&D experience", which means that having the third characteristic ("innovative ideas") together with the other two characteristics even decreases the likelihood of generating innovation output.

Turning now to R&D, we find that also in this case two of the three two-characteristics combinations show a mutually reinforcing effect: "R&D experience/innovative ideas" (as for innovation output) and "university-level education/innovative ideas". Contrary to innovation output, the three-characteristics combination yields in this case a mutually reinforcing effect.

Education and innovative ideas are not sufficient for performing R&D, obviously it needs in addition experience in R&D.

There is a policy implication of these results: it is advisable for public agencies supporting the foundation of new innovative firms that they would take these mutually reinforcing effects of founders' characteristics into account when assessing projects of start-ups.

4.5.2 Influence of changes in the composition of founding teams

Over time, changes in the composition of the founding teams (that are at the same time also management teams of the firms) are possible. The firms reported the characteristics of the founding team at the time of firm foundation, so it is possible that some of these factors may change later. The results of the estimates excluding firms with changes in the composition of the founding team are reported in Table 4.4. In the innovation output model, the effect of team foundations (TEAM_FOUNDATION) disappears. This means that the team effect found in Table 4.2 is traced back primarily to firms with changes in the composition of the founding team. In the R&D model, the variable for other tertiary level education (LEVEL_O_TERTIARY) now is positively correlated with R&D activities (the effect of LEVEL_O_TERTIARY is however significantly smaller than the effect of LEVEL_UNI). On the other hand, the effect of commercial know-how (TYPE_COMMERCIAL) becomes insignificant. We also find a significant positive effect of self-employment experience (EXP_SELF) that can be interpreted as a hint that this effect is discernible only for firms that kept their founding team, thus also their management team, unchanged.

Despite the fact that more than 20% of the firms reported changes in their management teams, excluding firms with such changes does only marginally affect our estimates.

Table 4.2: Estimates of innovative activity (random-effects probit)

Dependent variable	IP	dy/dx	R&D	dy/dx	Expected sign
Founder characteristics					
LEVEL_UNI	0.338***	0.111***	0.740***	0.090***	+
	(0.115)	(0.037)	(0.197)	(0.023)	
LEVEL_O_TERTIARY	0.081	0.027	0.235	0.029	+
	(0.092)	(0.030)	(0.168)	(0.020)	
TYPE_TECHNICAL	0.142	0.047	0.638***	0.078***	+
	(0.119)	(0.039)	(0.204)	(0.024)	
TYPE_COMMERCIAL	0.107	0.035	-0.363*	-0.044*	-
	(0.109)	(0.036)	(0.201)	(0.025)	
TYPE_MIX	0.234**	0.077**	0.312*	0.038*	?
	(0.111)	(0.036)	(0.189)	(0.023)	
EXP_IND	-0.008	-0.003	-0.299**	-0.037**	+
	(0.082)	(0.027)	(0.144)	(0.017)	
EXP_SELF	0.034	0.011	0.355	0.043	+
	(0.135)	(0.044)	(0.225)	(0.027)	
EXP_RAD	0.556***	0.182***	1.658***	0.202***	+
	(0.136)	(0.044)	(0.218)	(0.021)	
INNO_IDEA	0.313***	0.103***	0.679***	0.083***	+
	(0.081)	(0.026)	(0.146)	(0.017)	
LAGE	-0.116	-0.038	-0.106	-0.013	-
	(0.170)	(0.056)	(0.289)	(0.035)	
MALE_TEAM	0.052	0.017	0.527**	0.064**	+
	(0.135)	(0.044)	(0.265)	(0.032)	
MIXED_TEAM	-0.003	-0.001	0.254	0.031	?
	(0.165)	(0.054)	(0.309)	(0.038)	
TEAM_FOUNDATION	0.184*	0.060*	-0.028	-0.003	+
	(0.102)	(0.033)	(0.170)	(0.021)	
Firm characteristics					
LSIZE	0.043	0.014	0.023	0.003	+
	(0.055)	(0.018)	(0.087)	(0.011)	
EXPORT	0.483***	0.159***	0.589***	0.072***	+
	(0.088)	(0.028)	(0.130)	(0.016)	
DIVERSIFICATION	0.406***	0.133***	0.237*	0.029*	+
	(0.079)	(0.025)	(0.134)	(0.016)	
Market conditions					
DEMAND_FUTURE	0.280***	0.092***	0.362***	0.044***	+
	(0.075)	(0.024)	(0.122)	(0.015)	
COOPERATION	0.405***	0.133***	0.958***	0.117***	+
	(0.073)	(0.023)	(0.120)	(0.015)	
PCOMP	-0.074	-0.024	-0.130	-0.016	?
	(0.069)	(0.023)	(0.110)	(0.013)	
NPCOMP	0.268***	0.088***	0.093	0.011	?
	(0.069)	(0.022)	(0.111)	(0.014)	
MANUFACT	0.341*	0.112*	1.867***	0.228***	
	(0.191)	(0.062)	(0.409)	(0.049)	
MOD_SERV	0.144	0.047	1.197***	0.146***	
	(0.151)	(0.050)	(0.358)	(0.043)	
TRAD_SERV	0.274*	0.090*	1.161***	0.142***	
	(0.149)	(0.049)	(0.359)	(0.043)	
Y2003	-0.009	-0.003	-0.138	-0.017	
	(0.080)	(0.026)	(0.121)	(0.015)	
Y2006	-0.043	-0.014	-0.511***	-0.062***	
	(0.087)	(0.029)	(0.143)	(0.017)	
CONSTANT	-1.201*		-4.460***		
	(0.645)		(1.183)		
N	2393	2393	2393	2393	
Groups	1204		1204		
Wald chi^2	238.72***		179.83***		
Rho	0.357		0.629		
LR test of rho=0	70.19***		117.47***		

Notes: See Table 4.1 for the variable definitions; to estimate marginal effects, we fixed the group specific intercept at 0, but otherwise averaged the marginal effects over the other explanatory variables; standard errors are in brackets under the coefficients; ***, **, * denotes statistical significance at the 1%, 5% and 10% test level, respectively.

Table 4.3: Analyzing combinations of founder characteristics (random-effects probit)

Dependent variable	IP	dy/dx	R&D	dy/dx
u1_r0_i0	0.432**	0.141**	0.534*	0.064*
	(0.171)	(0.055)	(0.299)	(0.036)
u0_r1_i0	0.316	0.103	1.263***	0.150***
	(0.262)	(0.085)	(0.401)	(0.048)
u0_r0_i1	0.302***	0.099***	0.414**	0.049**
	(0.095)	(0.031)	(0.176)	(0.021)
u0_r1_i1	1.227***	0.401***	2.586***	0.308***
	(0.212)	(0.067)	(0.339)	(0.033)
u1_r0_i1	0.672***	0.219***	1.421***	0.169***
	(0.149)	(0.047)	(0.258)	(0.029)
u1_r1_i0	1.024***	0.335***	1.543***	0.184***
	(0.360)	(0.116)	(0.491)	(0.057)
u1_r1_i1	0.807***	0.264***	2.865***	0.341***
	(0.256)	(0.083)	(0.434)	(0.045)
LEVEL_O_TERTIARY	0.070	0.023	0.227	0.027
	(0.092)	(0.030)	(0.168)	(0.020)
TYPE_TECHNICAL	0.149	0.049	0.661***	0.079***
	(0.119)	(0.039)	(0.204)	(0.024)
TYPE_COMMERCIAL	0.108	0.035	-0.323	-0.039
	(0.109)	(0.036)	(0.200)	(0.024)
TYPE_MIX	0.221**	0.072**	0.352*	0.042*
	(0.111)	(0.036)	(0.190)	(0.022)
EXP_IND	-0.002	-0.001	-0.295**	-0.035**
	(0.082)	(0.027)	(0.144)	(0.017)
EXP_SELF	0.029	0.009	0.332	0.040
	(0.134)	(0.044)	(0.224)	(0.027)
LAGE	-0.109	-0.036	-0.162	-0.019
	(0.170)	(0.056)	(0.289)	(0.034)
MALE_TEAM	0.044	0.014	0.552**	0.066**
	(0.134)	(0.044)	(0.266)	(0.032)
MIXED_TEAM	-0.004	-0.001	0.299	0.036
	(0.164)	(0.054)	(0.309)	(0.037)
TEAM_FOUNDATION	0.180*	0.059*	-0.039	-0.005
	(0.101)	(0.033)	(0.169)	(0.020)
LSIZE	0.045	0.015	0.019	0.002
	(0.054)	(0.018)	(0.087)	(0.010)
EXPORT	0.483***	0.158***	0.601***	0.072***
	(0.088)	(0.028)	(0.130)	(0.016)
DIVERSIFICATION	0.413***	0.135***	0.236*	0.028*
	(0.079)	(0.025)	(0.134)	(0.016)
DEMAND_FUTURE	0.278***	0.091***	0.351***	0.042***
	(0.075)	(0.024)	(0.122)	(0.014)
COOPERATION	0.406***	0.133***	0.947***	0.113***
	(0.073)	(0.023)	(0.119)	(0.015)
PCOMP	-0.078	-0.025	-0.136	-0.016
	(0.069)	(0.022)	(0.110)	(0.013)
NPCOMP	0.268***	0.088***	0.096	0.011
	(0.069)	(0.022)	(0.111)	(0.013)
MANUFACT	0.306	0.100	1.768***	0.211***
	(0.190)	(0.062)	(0.402)	(0.047)
MOD_SERV	0.130	0.042	1.156***	0.138***
	(0.151)	(0.049)	(0.352)	(0.042)
TRAD_SERV	0.257*	0.084*	1.098***	0.131***
	(0.148)	(0.048)	(0.353)	(0.042)
Y2003	-0.009	-0.003	-0.145	-0.017
	(0.080)	(0.026)	(0.121)	(0.014)
Y2006	-0.044	-0.015	-0.518***	-0.062***
	(0.087)	(0.029)	(0.143)	(0.017)
CONSTANT	-1.208*		-4.090***	
	(0.648)		(1.177)	
N	2393	2393	2393	2393
Groups	1204		1204	
Wald chi^2	242.81***		180.94***	
Rho	0.353		0.625	
LR test of rho=0	68.34***		115.27***	

Reading Aid: u=LEVEL_UNI, r=EXP_RAD, i=INNO_IDEA; Combinations of these three binary variables: u0_r1_i1= a firm with LEVEL_UNI=0, EXP_RAD=1 and INNO_IDEA=1; u1_r0_i0= a firm with LEVEL_UNI=1, EXP_RAD=0 and INNO_IDEA=0; etc; reference group: u0_r0_i0.

Notes: See Table 4.1 for the variable definitions; to estimate marginal effects, we fixed the group specific intercept at 0, but otherwise averaged the marginal effects over the other explanatory variables; standard errors are in brackets under the coefficients; ***, **, * denotes statistical significance at the 1%, 5% and 10% test level, respectively.

Table 4.4: Estimates of innovative activity excluding firms with changes in the composition of the founding team (random-effects probit)

Dependent variable	IP	dy/dx	R&D	dy/dx	Expected sign
Founder characteristics					
LEVEL_UNI	0.412***	0.130***	0.979***	0.106***	+
	(0.136)	(0.042)	(0.250)	(0.026)	
LEVEL_O_TERTIARY	0.156	0.049	0.501**	0.054**	+
	(0.105)	(0.033)	(0.206)	(0.022)	
TYPE_TECHNICAL	0.167	0.053	0.705***	0.076***	+
	(0.139)	(0.044)	(0.247)	(0.026)	
TYPE_COMMERCIAL	0.153	0.049	-0.260	-0.028	-
	(0.126)	(0.040)	(0.238)	(0.026)	
TYPE_MIX	0.211*	0.067*	0.447**	0.048**	?
	(0.126)	(0.040)	(0.226)	(0.024)	
EXP_IND	-0.023	-0.007	-0.362**	-0.039**	+
	(0.094)	(0.030)	(0.170)	(0.018)	
EXP_SELF	0.120	0.038	0.610**	0.066**	+
	(0.167)	(0.053)	(0.285)	(0.031)	
EXP_RAD	0.667***	0.211***	1.833***	0.199***	+
	(0.167)	(0.051)	(0.278)	(0.022)	
INNO_IDEA	0.335***	0.106***	0.708***	0.077***	+
	(0.093)	(0.029)	(0.175)	(0.018)	
LAGE	-0.027	-0.008	-0.085	-0.009	-
	(0.192)	(0.061)	(0.336)	(0.036)	
MALE_TEAM	0.002	0.000	0.520*	0.056*	+
	(0.149)	(0.047)	(0.307)	(0.033)	
MIXED_TEAM	-0.049	-0.016	0.492	0.053	?
	(0.195)	(0.062)	(0.379)	(0.041)	
TEAM_FOUNDATION	0.141	0.044	-0.231	-0.025	+
	(0.130)	(0.041)	(0.224)	(0.024)	
Firm characteristics					
LSIZE	0.080	0.025	0.068	0.007	+
	(0.071)	(0.022)	(0.122)	(0.013)	
EXPORT	0.487***	0.154***	0.630***	0.068***	+
	(0.103)	(0.031)	(0.157)	(0.017)	
DIVERSIFICATION	0.525***	0.166***	0.205	0.022	+
	(0.092)	(0.027)	(0.159)	(0.017)	
Market conditions					
DEMAND_FUTURE	0.293***	0.093***	0.373**	0.040**	+
	(0.088)	(0.027)	(0.148)	(0.016)	
COOPERATION	0.447***	0.141***	1.062***	0.115***	+
	(0.084)	(0.026)	(0.154)	(0.016)	
PCOMP	-0.088	-0.028	-0.024	-0.003	?
	(0.080)	(0.025)	(0.132)	(0.014)	
NPCOMP	0.304***	0.096***	0.094	0.010	?
	(0.080)	(0.025)	(0.135)	(0.015)	
MANUFACT	0.313	0.099	2.017***	0.219***	
	(0.211)	(0.066)	(0.470)	(0.049)	
MOD_SERV	0.085	0.027	1.210***	0.131***	
	(0.168)	(0.053)	(0.406)	(0.043)	
TRAD_SERV	0.207	0.066	0.959**	0.104**	
	(0.163)	(0.051)	(0.401)	(0.043)	
Y2003	-0.022	-0.007	-0.359**	-0.039**	
	(0.094)	(0.030)	(0.152)	(0.016)	
Y2006	-0.007	-0.002	-0.729***	-0.079***	
	(0.104)	(0.033)	(0.187)	(0.020)	
CONSTANT	-1.613**		-4.849***		
	(0.731)		(1.398)		
N	1875	1875	1875	1875	
Groups	1026		1026		
Wald chi^2	199.80***		117.50***		
Rho	0.378		0.654		
LR test of rho=0	55.42***		77.95***		

Notes: See Table 4.1 for the variable definitions; to estimate marginal effects, we fixed the group specific intercept at 0, but otherwise averaged the marginal effects over the other explanatory variables; standard errors are in brackets under the coefficients; ***, **, * denotes statistical significance at the 1%, 5% and 10% test level, respectively.

Table 4.5: Estimates of the persistence of innovative activity (multinomial logit estimates; base category: firms with discontinuous innovative activities)

Dependent variable	IP		R&D	
	no	persistently	no	persistently
Founder characteristics				
LEVEL_UNI	-0.746**	0.286	-0.683*	0.329
	(0.377)	(0.366)	(0.378)	(0.609)
LEVEL_O_TERTIARY	-0.553**	-0.405	-0.215	-0.073
	(0.280)	(0.323)	(0.336)	(0.549)
TYPE_TECHNICAL	0.236	0.199	-0.075	0.910
	(0.349)	(0.420)	(0.395)	(0.690)
TYPE_COMMERCIAL	0.246	0.488	0.669*	0.165
	(0.323)	(0.402)	(0.395)	(0.803)
TYPE_MIX	-0.195	0.458	-0.075	0.596
	(0.364)	(0.394)	(0.380)	(0.646)
EXP_IND	-0.214	-0.323	0.497*	0.047
	(0.256)	(0.296)	(0.287)	(0.503)
EXP_SELF	-0.146	-0.251	0.649	1.158
	(0.462)	(0.520)	(0.553)	(0.799)
EXP_RAD	-1.525**	0.228	-1.299***	1.720***
	(0.620)	(0.394)	(0.452)	(0.505)
INNO_IDEA	-0.480*	0.443	-0.889***	0.507
	(0.251)	(0.287)	(0.285)	(0.523)
LAGE	0.577	0.583	0.099	-1.484*
	(0.517)	(0.571)	(0.672)	(0.869)
GENDER	-0.324	-0.110	-0.225	0.091
	(0.293)	(0.315)	(0.312)	(0.588)
TEAM_FOUNDATION	-0.419	0.184	-0.552*	-0.887*
	(0.297)	(0.304)	(0.324)	(0.527)
Firm characteristics				
LSIZE	0.355	0.805**	-0.389	0.383
	(0.341)	(0.337)	(0.362)	(0.522)
EXPORT	0.141	0.832***	-0.635**	0.278
	(0.319)	(0.272)	(0.285)	(0.415)
DIVERSIFICATION	-0.871***	0.207	-0.386	0.460
	(0.253)	(0.268)	(0.268)	(0.425)
Market conditions				
DEMAND_FUTURE	-0.744***	0.534	-0.331	0.636
	(0.286)	(0.381)	(0.332)	(0.577)
COOPERATION	-0.421	0.417	-0.875***	0.773*
	(0.264)	(0.264)	(0.275)	(0.432)
PCOMP	0.217	-0.008	0.775***	-0.129
	(0.246)	(0.275)	(0.268)	(0.439)
NPCOMP	-0.653***	0.581**	-0.061	-0.292
	(0.245)	(0.276)	(0.269)	(0.406)
MANUFACT	0.354	1.331*	-2.523***	-0.944
	(0.585)	(0.757)	(0.893)	(1.214)
MOD_SERV	0.185	1.097*	-2.047***	-1.157
	(0.405)	(0.639)	(0.761)	(1.165)
TRAD_SERV	-0.260	1.077*	-1.316*	-0.942
	(0.411)	(0.630)	(0.784)	(1.159)
CONSTANT	-0.532	-6.611***	4.572*	2.510
	(1.944)	(2.275)	(2.634)	(3.568)
N	484		484	
Wald chi^2	143.79***		176.38***	

Notes: We define the following categorical variables to measure the persistence of innovative activities: no (firm has no innovative activities), discontinuously (firm has in some cross-sections innovative activities) and persistently (firm has in all three cross-sections innovative activities); see Table 4.1 for the variable definitions; heteroskedasticity-robust standard errors (White procedure) are in brackets under the coefficients; a Hausman test does not reject the null hypothesis that the assumption of independence of irrelevant alternatives (IIA-assumption) is fulfilled in any single case (suest-based Hausman test implemented in Stata); standard errors are in brackets under the coefficients; ***, **, * denotes statistical significance at the 1%, 5% and 10% test level, respectively.

4.5.3 Persistently innovative start-ups

So far we have considered all firms that have had innovation activities in some point of time. However, it would be interesting to know whether founder characteristics also correlate with the *persistence* of innovation over time. In order to investigate such differences, we estimate a multinomial logit model including only firms that answered all three questionnaires and choose the base category so that we can analyze whether the effects of founder characteristics differ for firms that have in each cross-section (persistently) innovative activities from firms with discontinuous innovative activities.[6] Estimation results for firms without innovation activities in any point of time confirm previous results (column 1 and 3 in Table 4.5). The reduction of the sample size thus does only marginally affect the estimation results.

The results for the firms with continuous innovation activities show that founder characteristics are *not* the main factors correlating with the persistence of innovation in start-ups (see column 2 and 4 of Table 4.5). The coefficients of all founder characteristics variables are statistically insignificant in the innovation output estimates, only a few of them are significant in the innovation input estimates. R&D experience (EXP_RAD) seems to be significantly more important in firms that have had in each cross-section R&D activities than in firms with discontinuous R&D activities. Further, founding teams with a high average age (LAGE) tend to invest less in innovation input. This is intuitively plausible, as investment costs increase with persistent innovation activities, whereby risk behavior of the firm founders gets even more important. Surprisingly, we find a weak negative effect of team foundations (TEAM_FOUNDATION) on the persistence of R&D activities. However, this effect is primarily driven by a strong correlation with the variable LSIZE (r= 0.33). While this correlation does not affect the results in the estimates based on all observations, in this regression the significant negative effect for the variable TEAM_FOUNDATION disappears, when we do not control for firm size.

[6] See the note in Table 4.5 for the construction of the dependent variables for the multinomial logit model. Because we do not have enough observations for each of the three categories to test the gender effect in detail as in the previous models, we include just a single variable measuring the dominant gender of the founding team (GENDER) in the estimates in Table 4.5.

In sum, we conclude that the founders' characteristics are primarily related to the likelihood of a firm getting engaged in innovative activities but not to the persistence of such innovative activities over time.

Firm size (LSIZE) is positively correlated with innovation persistence. Further factors with (partly) positive effects either on innovation output or innovation input are the degree of exposition to international competition as measured by the existence of exporting activities (EXPORT), the intensity of non-price competition (NPCOMP), and finally the existence of cooperation with other firms/institutes (COOPERATION).

4.6 Comparison with existing empirical literature

We could find only two empirical studies that deal with the innovation capabilities of firm founders in start-ups. A third study comes near to our topic as it investigates the influence of human capital and other related founders' characteristics on the growth perspectives of new technology-based firms. The first one is the study of Lynskey (2004) that analyzes the impact of the CEO characteristics based on Japanese firm-level data. In this study, innovative activity is measured by the number of patent applications and the number of new products. Several managerial variables are included in the estimated models. They also include a variable that captures effects of the education level of the CEO, a dummy that measures whether the CEO has previous R&D experience and a variable that denotes the age of the CEO. Moreover, they test the impact of management experience and whether the CEO is engaged in a research network. An additional variable denotes whether the CEO is also the founder of the firm, so that possible differences between these two functions can be captured. However, only a few of these variables show statistically significant effects on innovation activity. While in the new product regression no variable significantly correlates, R&D experience and a research network positively affect the number of patent applications of the start-ups. In contrast with our results, managerial characteristics show no explanatory power in their models. An explanation could be that the firms in their sample are much larger than our firms. While the average age of the firms is quite similar, average sales of their firms are above 1.5 million USD compared with 0.1 million USD in our sample. We would expect that the CEO is less directly involved in the innovation process in such large firms than in smaller firms.

Accordingly, the impact on innovative activities should be more limited. Further, the CEO is probably only one person of a founding team that as a whole may have a stronger impact on innovation activities of the start-ups.

In a second study Koch & Strotmann (2008) analyze the impact of founder characteristics on the innovation performance of German start-ups in the knowledge-intensive business sector. They distinguish two categories of innovation performance, incremental innovation and radical innovation. As independent variables they include variables describing the characteristics of one firm founder such as age and sex. Further, they use information on this founder's last occupation before the foundation (university, private economy or self-employed) as a proxy for the professional background of the founder. Beside a dummy for team foundations, they also have information on whether a concrete idea from the founder's former occupation was decisive for the foundation, what is similar to the variable INNO_IDEA in our study. Similar to Lynskey (2004), Koch & Strotmann (2008) find only a few significant effects. Male founders tend to have more radical innovations than female founders and firms of founders that were self-employed before foundation have fewer innovations (incremental and radical) than firms of founders that worked in the private economy. All other variables that describe the founder characteristics do not significantly affect the innovation performance. Concerning firm size, the firms in their sample are quite similar to the firms in our sample. While their firms on average have 4.5 employees, the firms in our sample have on average 1.6 employees. However, it is questionable whether the information on one founder's last occupation adequately describes the professional background of the whole founding team. This information is only available for one founder per firm (about 60% of the firms were team foundations) and is also not available for previous occupations of the founders. A dummy variable that measures whether the background of the founders is diversified can only partially solve this problem.

Based on a sample of 506 Italian young firms in high-tech industries in both manufacturing and services Colombo & Grill (2005) find that the nature of the education and of the prior experience of founders exerts a significant influence on firm performance. More concretely, founders' years of economic and managerial education and to a lesser extent scientific and technical education positively affect economic performance, while education in other fields

does not. Furthermore, technical work experience as well as prior entrepreneurial experience seem to contribute significantly to superior economic performance. Even if the target variable is not the same as in our study (employment growth vs. innovation performance), the results point in the same direction as ours.

4.7 Conclusions

As most start-ups are not growth-drivers, the allocation of start-up subsidies has important policy implications. Misallocation may keep inefficient firms on the market and/or lead to a crowding out effect of non-subsidized firms. Policy makers should thus focus on firms with high growth potential and stop subsidizing typical start-ups (Shane 2009). Accordingly, it is important to be able to identify firms with a high probability of enhancing economic growth. As innovation performance is a crucial precondition for the growth of such firms, identifying factors that determine whether a young firm would have innovative activities or not seems to be an important step in this direction. So far it is unclear how innovative start-ups look like. In this paper we investigate whether information on the founder characteristics is correlated with the innovative activity of start-ups.

Following pattern emerges from our estimates: the ability of start-ups to conduct R&D *and* introduce innovative products depends on founders having a university education (at best mixed technical and commercial), prior experience in R&D, and – especially important – strong motivation to realize own innovative ideas. There are also mutually reinforcing effects of these three characteristics, especially with respect to R&D activities. Team foundations perform better than single founders with respect to sales of innovative products, but not with respect to R&D.

All in all, we conclude that knowing the founder characteristics would help policy makers to identify the innovative start-ups already in the beginning and thus to increase efficiency of start-up subsidies, given that such a promotion policy is pursued. A further reason to use founder characteristics as selection criteria for subsidies is that they are easily observable and remain constant over time. Accordingly, the identification of innovative start-ups would be possible at relatively low costs. This applies all the more as changes in the composition of the founding team have no discernible influence on the innovation activities of the firms. On the

other hand, the use of these variables as identification variables may be limited, as founder characteristics seem to determine whether a firm gets engaged in innovative activities but not whether such activities are persistent over time (with the exception of experience in R&D). Based on founder information, it is not possible to distinguish between start-ups that have persistent innovation activities and firms with discontinuous innovation activities.

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A Appendix to Chapter 2

Table A.1: Descriptive statistics (means of variables included in training equations)

Dependent variable	training_propensity			training_intensity			
Explanatory variable	Whole data set (N=3005)	Cross-section 2000 (N=1389)	Cross-section 2005 (N=1616)	Whole data set (N=2274)	Cross-section 2000 (N=1029)	Cross-section 2005 (N=1245)	Explanatory variable
training_propensity	0.76	0.74	0.77	1.77	1.74	1.79	training_intensity
tertiary_share	1.98	1.81	2.13	2.19	2.01	2.34	tertiary_share
intranet_use_d1	0.24	0.23	0.24	0.25	0.25	0.26	intranet_use_d1
intranet_use_d2	0.21	0.17	0.25	0.22	0.17	0.25	intranet_use_d2
Internet_variety	4.41	4.32	4.48	4.52	4.43	4.59	Internet_variety
ICT_infrustructure	3.39	3.37	3.41	3.44	3.43	3.44	ICT_infrustructure
Δ_hierarchical_levels	0.12	0.16	0.09	0.12	0.16	0.09	Δ_hierarchical_levels
Δ_delegation	0.44	0.56	0.34	0.44	0.56	0.34	Δ_delegation
decentralization	2.38	2.35	2.41	2.38	2.33	2.41	decentralization
job_rotation	0.57	0.64	0.51	0.57	0.62	0.52	job_rotation
team_work	2.22	2.18	2.25	2.31	2.25	2.35	team_work
labor_costs	11.29	11.24	11.33	11.29	11.24	11.34	labor_costs
foreign_owned	0.16	0.16	0.16	0.14	0.14	0.15	foreign_owned
size_d1	0.28	0.30	0.27	0.23	0.24	0.22	size_d1
size_d2	0.24	0.25	0.23	0.24	0.25	0.23	size_d2
size_d3	0.26	0.25	0.27	0.28	0.27	0.29	size_d3
size_d4	0.11	0.10	0.12	0.13	0.13	0.14	size_d4
size_d5	0.05	0.05	0.05	0.06	0.06	0.05	size_d5
size_d6	0.04	0.04	0.05	0.05	0.05	0.05	size_d6

Notes: The variables “tertiary_share” and “labor_costs” are logarithms, the other ones are either ordinal or nominal (dummies) variables.

Table A.2: Correlation matrix (N= 3005)

	tertiary_share	ICT_total	intranet_use_d1	intranet_use_d2	Internet_variety	ICT_infrustructure	WO_total	Δ_hierarchical_levels	Δ_delegation	decentralization
ICT_total	0.260									
intranet_use_d1	0.069	0.223								
intranet_use_d2	0.161	0.579	-0.287							
Internet_variety	0.154	0.755	0.070	0.245						
ICT_infrustructure	0.235	0.803	0.214	0.260	0.432					
WO_total	0.150	0.320	0.115	0.169	0.253	0.245				
Δ_hierarchical_levels	0.029	0.101	0.071	0.030	0.078	0.085	0.521			
Δ_delegation	0.072	0.122	0.072	0.027	0.108	0.112	0.625	0.216		
decentralization	0.134	0.251	0.053	0.209	0.157	0.173	0.513	0.072	0.178	
job_rotation	0.023	0.087	0.043	-0.007	0.113	0.066	0.493	0.065	0.121	-0.009
team_work	0.153	0.317	0.077	0.202	0.237	0.234	0.587	0.075	0.197	0.165
labor_costs	0.207	0.268	0.036	0.278	0.134	0.176	0.100	0.023	-0.014	0.149
foreign_owned	0.069	0.173	0.051	0.147	0.078	0.133	0.117	0.034	0.056	0.124
size_d1	-0.109	-0.241	-0.093	-0.108	-0.143	-0.233	-0.125	-0.050	-0.017	-0.071
size_d2	-0.023	-0.060	-0.001	-0.063	-0.030	-0.048	-0.025	-0.010	-0.004	-0.063
size_d3	0.070	0.066	0.051	-0.005	0.021	0.104	0.026	0.012	0.007	0.009
size_d4	0.068	0.144	0.063	0.070	0.081	0.139	0.073	0.034	-0.004	0.059
size_d5	0.054	0.129	0.023	0.103	0.073	0.098	0.085	0.011	0.045	0.073
size_d6	0.044	0.203	0.017	0.177	0.150	0.123	0.110	0.038	0.009	0.118

	job_rotation	team_work	labor_costs	foreign_owned	size_d1	size_d2	size_d3	size_d4	size_d5
team_work	0.171								
labor_costs	-0.037	0.153							
foreign_owned	0.001	0.107	0.147						
size_d1	-0.036	-0.169	-0.107	-0.083					
size_d2	0.039	-0.031	-0.033	-0.037	-0.350				
size_d3	-0.016	0.058	0.042	0.068	-0.368	-0.333			
size_d4	0.003	0.108	0.057	0.043	-0.219	-0.198	-0.208		
size_d5	0.004	0.100	0.069	0.064	-0.139	-0.126	-0.132	-0.079	
size_d6	0.038	0.100	0.062	-0.019	-0.130	-0.118	-0.124	-0.074	-0.047

Table A.3: Testing for sample selection (Heckman selection model)

	OLS	Heckman	
Dependent variable	Training intensity	Training intensity	Training propensity
tertiary_share	0.017**	0.019**	0.033***
	(0.008)	(0.009)	(0.009)
ICT_total	0.015	0.017	0.049***
	(0.010)	(0.011)	(0.014)
WO_total	0.011*	0.011	-0.012
	(0.007)	(0.007)	(0.011)
labor_costs	-0.295***	-0.302***	-0.168*
	(0.066)	(0.068)	(0.092)
foreign_owned	-0.062	-0.078	-0.388***
	(0.051)	(0.070)	(0.075)
size_d1	0.377**	0.388**	0.197
	(0.149)	(0.151)	(0.169)
size_d2	0.731***	0.760***	0.585***
	(0.150)	(0.171)	(0.171)
size_d3	1.343***	1.385***	0.914***
	(0.151)	(0.193)	(0.172)
size_d4	2.047***	2.102***	1.363***
	(0.154)	(0.222)	(0.195)
size_d5	2.781***	2.832***	1.181***
	(0.164)	(0.221)	(0.217)
size_d6	4.068***	4.131***	1.653***
	(0.181)	(0.249)	(0.251)
year_2005	0.042	0.045	0.088
	(0.036)	(0.037)	(0.055)
wage_individual_performance	-0.002		0.084**
	(0.023)		(0.033)
constant	2.617***	2.580***	0.818
	(0.761)	(0.774)	(1.086)
Region dummies	yes	yes	yes
Industry dummies	yes	yes	yes
N	2274	2274	
F	61.14***		
R^2	0.588		
Wald chi^2		1764.64***	
rho		0.124	
LR test of rho=0: Prob > chi^2		0.736	

Notes: See Table 2.1 for the variable definitions; standard errors are in brackets under the coefficients; ***, **, * denotes statistical significance at the 1%, 5% and 10% test level, respectively.

Table A.4: Testing for endogeneity (Rivers-Vuong-Test)

Dependent variable	training_propensity			training_intensity		
Tested variable	ICT_total	WO_total	tertiary_share	ICT_total	WO_total	tertiary_share
Instruments	industry level of intranet use	industry level of decentralization	industry level of tertiary share	industry level of intranet use	industry level of decentralization	industry level of tertiary share
Validity test of instruments:						
• Correlation with dependent variable in first stage (instrument equation)	yes	yes	yes	yes	yes	yes
• Correlation with dependent variable in second stage (training equation)	no	no	no	no	no	no
• Correlation with the residuals of the endogenized estimation	no	no	no	no	no	no
Rivers-Vuong-Test:						
• Chi^2	0.21	0.07	1.13	1.66	1.93	0.32
• $Prob>Chi^2$	0.645	0.797	0.288	0.197	0.165	0.572

Notes: For definition of the instruments see Table 2.1; the training equations are specified as in column 1 of Table 2.2 and Table 2.3, respectively; the instrument equations are specified as the training equations with the exception of the tested variables that are replaced by the instrument variables.

B Appendix to Chapter 3

Table B.1: Descriptive statistics

Period	2000 (N=1589)		2003 (N=911)		2006 (N=615)	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
SURVIVING	0.824	0.381	0.907	0.291		
BREAK	0.722	0.448	0.782	0.413	0.833	0.374
MAIN	0.831	0.375	0.849	0.359	0.852	0.355
UNEMPLOY	0.130	0.336	0.134	0.341	0.140	0.347
LAGE	3.652	0.217	3.656	0.210	3.650	0.212
GENDER	0.767	0.423	0.751	0.433	0.750	0.434
QUAL	0.659	0.474	0.697	0.460	0.691	0.462
R&D	0.234	0.424	0.189	0.392	0.154	0.362
NP	0.149	0.356	0.112	0.315	0.124	0.329
MP	0.403	0.491	0.387	0.487	0.372	0.484
PCOMP	0.422	0.494	0.483	0.500	0.486	0.500
NPCOMP	0.536	0.499	0.526	0.500	0.515	0.500
LCAP	10.553	1.959	10.559	1.832	10.537	1.788
AG	0.163	0.369	0.181	0.385	0.151	0.359
GmbH	0.254	0.436	0.262	0.440	0.306	0.461
OTHER	0.097	0.296	0.041	0.198	0.041	0.198
LSIZE	1.069	0.555	1.150	0.632	1.186	0.716
IND_1	0.084	0.278	0.080	0.272	0.081	0.274
IND_2	0.444	0.497	0.462	0.499	0.506	0.500
IND_3	0.379	0.485	0.368	0.482	0.320	0.467
DEBT_CONST	0.002	2.621	0.011	2.626	-0.024	2.671
CRED_COND	2.047	1.514	2.113	1.419	1.896	1.406
CRED_LINE	2.014	1.502	2.019	1.354	1.789	1.341
DEBT_INFO	1.711	1.282	1.699	1.138	1.511	1.027
VC_CONST	1.566	1.169	1.529	1.098	1.395	0.971

Table B.2: Test for selective attrition (selection indicator included in success models; probit estimates)

Dependent variable	BREAK			
Period	2000		2003	
Explanatory variables	(1)	(2)	(3)	(4)
CONSTANT	0.400 (0.617)	0.265 (0.618)	0.016 (0.886)	0.211 (0.887)
MAIN	0.335*** (0.090)	0.308*** (0.091)	0.290** (0.131)	0.282** (0.130)
UNEMPLOY	-0.110 (0.104)	-0.113 (0.103)	-0.148 (0.140)	-0.153 (0.138)
LAGE	-0.040 (0.164)	0.041 (0.162)	0.093 (0.230)	0.085 (0.230)
GENDER	0.087 (0.084)	0.069 (0.084)	0.113 (0.114)	0.115 (0.114)
QUAL	0.088 (0.078)	0.125 (0.077)	0.148 (0.110)	0.172 (0.111)
R&D	-0.088 (0.093)	-0.076 (0.094)	-0.285** (0.128)	-0.296** (0.128)
NP	-0.111 (0.099)	-0.130 (0.099)	0.460*** (0.170)	0.463*** (0.169)
MP	0.082 (0.077)	0.071 (0.077)	0.145 (0.105)	0.137 (0.105)
PCOMP	-0.066 (0.071)	-0.069 (0.070)	-0.013 (0.097)	-0.037 (0.096)
NPCOMP	0.041 (0.072)	0.041 (0.072)	0.183* (0.097)	0.186* (0.097)
LCAP	-0.017 (0.020)	-0.017 (0.020)	0.001 (0.027)	-0.001 (0.027)
AG	0.118 (0.115)	0.095 (0.114)	-0.366** (0.151)	-0.346** (0.151)
GmbH	-0.146* (0.087)	-0.157* (0.087)	-0.341*** (0.116)	-0.339*** (0.116)
OTHER	-0.025 (0.123)	-0.037 (0.123)	-0.032 (0.248)	-0.000 (0.248)
LSIZE	0.180* (0.108)	0.172 (0.106)	-0.058 (0.100)	-0.067 (0.101)
IND_1	-0.381** (0.163)	-0.363** (0.164)	-0.104 (0.233)	-0.099 (0.234)
IND_2	0.168 (0.135)	0.215 (0.135)	-0.050 (0.186)	-0.044 (0.188)
IND_3	-0.325** (0.131)	-0.304** (0.131)	0.044 (0.183)	0.028 (0.184)
DEBT_CONST	-0.067*** (0.013)		-0.051*** (0.018)	
VC_CONST		-0.107*** (0.029)		-0.094** (0.041)
INSAMPLE	0.219*** (0.070)	0.224*** (0.070)	0.199** (0.102)	0.209** (0.101)
N	1589	1589	911	911
McFadden's R^2	0.080	0.074	0.054	0.051
Wald chi^2	140.10***	130.11***	53.56***	50.07***

Notes: See Table 3.1 for the variable definitions; heteroskedasticity-robust standard errors (Huber-White sandwich estimator) are in brackets under the coefficients; ***, **, * denotes statistical significance at the 1%, 5% and 10% test level, respectively.

Table B.3: Multinomial probit estimations used to compute the inverse probability weights [reference: $P(NOANSWER_{it} \cap SURVIVAL_{it})$]

Period	2000		2003		2006	
Explanatory variables	NONSURVIVAL	ANSWER ∩ SURVIVAL	NONSURVIVAL	ANSWER ∩ SURVIVAL	NONSURVIVAL	ANSWER ∩ SURVIVAL
CONSTANT	0.656***	-0.520***	0.733*	1.275***	-3.027*	1.079
	(0.144)	(0.167)	(0.394)	(0.355)	(1.623)	(1.101)
LAGE					0.727*	-0.076
					(0.431)	(0.294)
GENDER			0.050	-0.201*		
			(0.141)	(0.121)		
R&D			0.288**	0.298**		
			(0.146)	(0.126)		
MP			-0.314**	-0.178*		
			(0.123)	(0.105)		
LCAP			-0.064**	-0.020		
			(0.031)	(0.029)		
AG			-0.051	-0.105	-0.622**	-0.427**
			(0.181)	(0.158)	(0.277)	(0.196)
GmbH			-0.041	-0.189	-0.416*	0.108
			(0.140)	(0.122)	(0.221)	(0.158)
OTHER			0.180	0.322*	-0.708	-0.582*
			(0.208)	(0.181)	(0.436)	(0.315)
LSIZE	-0.475***	-0.149**	-0.221*	-0.134	-0.521***	0.041
	(0.058)	(0.060)	(0.115)	(0.097)	(0.197)	(0.113)
IND_1	0.182	0.138	-0.360	-0.246	0.760*	0.203
	(0.115)	(0.124)	(0.269)	(0.229)	(0.450)	(0.313)
IND_2	0.186**	0.248***	0.155	0.172	0.516	0.368
	(0.088)	(0.095)	(0.206)	(0.178)	(0.373)	(0.234)
IND_3	0.406***	-0.002	-0.165	-0.127	0.444	-0.226
	(0.085)	(0.094)	(0.206)	(0.179)	(0.365)	(0.232)
REG_1	0.129	0.150				
	(0.122)	(0.148)				
REG_2	0.163	0.626***				
	(0.121)	(0.146)				
REG_3	0.222*	0.593***				
	(0.124)	(0.148)				
REG_4	0.142	0.628***				
	(0.119)	(0.143)				
REG_5	0.241*	0.706***				
	(0.126)	(0.150)				
REG_6	0.210	0.591***				
	(0.128)	(0.152)				
N	7112		1625		945	
Wald chi^2	244.31***		49.49***		58.86***	

Notes: See Table 3.1 for the variable definitions; heteroskedasticity-robust standard errors (Huber-White sandwich estimator) are in brackets under the coefficients; ***, **, * denotes statistical significance at the 1%, 5% and 10% test level, respectively. To increase the model quality we excluded variables with insignificant effects. As usual in empirical literature, we control in each model for sector affiliation.

Table B.4: Testing DEBT_CONST for endogeneity (Rivers-Vuong-Test)

Dependent variable	SURVIVING		BREAK		
Period	2000-2003	2003-2006	2000	2003	2006
Instruments:	T_MARK_SHARE T_NEW_TECH WEALTH_SHARE	T_MARK_SHARE T_NEW_PROD	T_NEW_TECH SHORT T_MARK_SHARE	T_NEW_TECH BUS_PLAN	T_MARK_SHARE WEALTH_SHARE
Validity test of instruments:					
Correlation with dependent variable in first stage (instrument equation)	yes	yes	yes	yes	yes
Correlation with dependent variable in second stage (structural equation)	no	no	no	no	no
Correlation with the residuals for the endogenized estimation	no	no	no	no	no
Test of over identifying restrictions (prob>chi^2):	0.677	0.635	0.474	0.169	0.630
Results of Rivers-Vuong-Test:					
Chi^2	0.21	0.76	1.17	1.07	0.17
prob>chi^2	0.650	0.383	0.279	0.301	0.681

Notes: For definition of the instruments see Table 3.1; the structural equations are specified as in Table 3.2 and Table 3.3, respectively; the instrument equations are specified as the training equations with the exception of the tested variables that are replaced by the instrument variables.

Table B.5: Testing VC_CONST for endogeneity (Rivers-Vuong-Test)

Dependent variable	SURVIVING		BREAK		
Period	2000-2003	2003-2006	2000	2003	2006
Instruments:	T_MARK_SHARE T_NEW_TECH	T_MARK_SHARE T_NEW_PROD	T_MARK_SHARE SHORT	T_NEW_TECH BUS_PLAN	T_MARK_SHARE BUS_PLAN
Validity test of instruments:					
Correlation with dependent variable in first stage (instrument equation)	yes	yes	yes	yes	yes
Correlation with dependent variable in second stage (structural equation)	no	no	no	no	no
Correlation with the residuals for the endogenized estimation	no	no	no	no	no
Test of over identifying restrictions (prob>chi^2):	0.639	0.560	0.813	0.177	0.636
Results of Rivers-Vuong-Test:					
Chi^2	0.80	0.40	0.02	1.10	0.03
prob>chi^2	0.371	0.525	0.889	0.295	0.852

Notes: For definition of the instruments see Table 3.1; the structural equations are specified as in Table 3.2 and Table 3.3, respectively; the instrument equations are specified as the training equations with the exception of the tested variables that are replaced by the instrument variables.

Table B.6: Correlation matrix

Correlation matrix for cross-section 2000 (N=1589)

	SURVIVING	BREAK	MAIN	UNEMPLOY	LAGE	GENDER	QUAL	R&D	NP	MP	PCOMP	NPCOMP	LCAP	AG	GmbH	OTHER	LSIZE	IND_1	IND_2	IND_3	DEBT_ CONST	CRED_ COND	CRED_ LINE	DEBT_ INFO
BREAK	0.101																							
MAIN	0.070	0.114																						
UNEMPLOY	0.026	-0.041	0.044																					
LAGE	0.035	0.029	0.046	0.066																				
GENDER	-0.036	0.062	0.057	0.054	0.017																			
QUAL	-0.011	0.090	-0.019	-0.078	0.098	0.052																		
R&D	-0.011	-0.008	-0.041	0.017	0.037	0.063	0.188																	
NPCOMP	-0.025	-0.052	-0.066	-0.025	-0.012	0.018	0.063	0.232																
MP	0.046	0.038	0.004	-0.008	0.000	0.005	0.132	0.327	0.023															
PCOMP	-0.024	-0.044	-0.016	0.004	-0.048	-0.025	-0.027	-0.021	0.003	-0.017														
NPCOMP	-0.015	0.028	0.013	0.006	-0.028	0.042	0.079	0.127	0.071	0.189	0.100													
LCAP	0.072	-0.009	0.071	-0.057	0.115	0.017	0.030	0.009	-0.002	0.028	0.054	0.033												
AG	0.029	0.072	0.003	-0.109	0.065	0.107	0.123	0.062	0.031	0.137	-0.001	0.052	0.206											
GmbH	-0.008	-0.073	-0.034	-0.053	-0.052	-0.207	-0.016	0.029	0.011	0.009	0.083	0.016	-0.046	-0.258										
OTHER	0.006	0.009	-0.017	0.007	-0.002	-0.020	0.038	0.005	-0.030	-0.014	-0.039	-0.045	-0.036	-0.145	-0.191									
LSIZE	0.044	0.054	0.080	-0.121	-0.035	0.012	0.104	0.050	0.066	0.134	0.014	0.029	0.184	0.441	0.033	-0.069								
IND_1	0.021	-0.085	0.022	0.072	0.020	0.028	-0.111	0.084	0.013	0.004	0.025	0.005	-0.006	-0.017	0.036	-0.008	-0.014							
IND_2	-0.044	0.195	0.044	-0.051	0.065	0.104	0.285	0.149	0.003	0.095	-0.030	0.135	-0.050	0.117	-0.015	0.011	-0.050	-0.271						
IND_3	0.037	-0.172	-0.109	0.000	-0.034	-0.188	-0.155	-0.119	0.030	-0.058	0.002	-0.075	0.071	-0.095	0.012	-0.019	0.000	-0.237	-0.697					
DEBT_ CONST	-0.045	-0.163	0.010	0.053	-0.148	0.018	-0.091	0.071	0.081	0.056	0.082	0.012	-0.002	0.034	0.046	-0.024	0.071	0.071	-0.147	0.104				
CRED_ COND	-0.048	-0.152	0.005	0.023	-0.141	0.007	-0.079	0.038	0.077	0.042	0.088	0.007	0.012	0.032	0.061	-0.038	0.070	0.059	-0.156	0.108	0.893			
CRED_ LINE	-0.032	-0.153	0.026	0.054	-0.114	0.037	-0.084	0.065	0.073	0.053	0.088	-0.005	0.034	0.056	0.034	-0.023	0.095	0.080	-0.136	0.077	0.902	0.769		
DEBT_ INFO	-0.038	-0.123	-0.005	0.062	-0.133	0.003	-0.076	0.083	0.063	0.052	0.039	0.029	-0.051	0.001	0.026	-0.002	0.020	0.046	-0.094	0.086	0.825	0.569	0.592	
VC_ CONST	-0.019	-0.123	-0.047	0.060	-0.065	-0.013	0.046	0.162	0.080	0.079	0.077	0.030	-0.011	0.030	0.038	-0.024	0.032	0.051	-0.047	0.068	0.490	0.428	0.432	0.423

Correlation matrix for cross-section 2003 (N=911)

	SURVIVING	BREAK	MAIN	UNEMPLOY	LAGE	GENDER	QUAL	R&D	NP	MP	PCOMP	NPCOMP	LCAP	AG	GmbH	OTHER	LSIZE	IND_1	IND_2	IND_3	DEBT_ CONST	CRED_ COND	CRED_ LINE	DEBT_ INFO
BREAK	0.050																							
MAIN	0.012	0.073																						
UNEMPLOY	-0.029	-0.026	0.067																					
LAGE	-0.089	0.018	0.051	0.070																				
GENDER	-0.010	0.039	0.061	0.048	0.012																			
QUAL	0.043	0.045	-0.039	-0.091	0.076	0.062																		
R&D	0.010	-0.064	-0.062	0.000	-0.044	0.064	0.098																	
NPCOMP	0.006	0.070	-0.044	-0.027	-0.034	0.028	0.037	0.211																
MP	0.023	0.017	-0.003	-0.002	-0.039	-0.016	0.088	0.267	0.082															
PCOMP	-0.007	-0.021	0.010	0.007	-0.062	-0.027	0.040	0.016	0.040	0.025														
NPCOMP	-0.010	0.051	-0.015	0.031	-0.014	-0.029	0.034	0.076	0.044	0.106	0.029													
LCAP	0.001	-0.004	0.062	-0.048	0.114	0.044	0.033	0.001	-0.026	0.070	0.014	0.062												
AG	0.073	-0.055	-0.040	-0.110	0.057	0.119	0.118	0.079	0.113	0.094	0.030	0.059	0.174											
GmbH	0.080	-0.083	-0.013	-0.022	-0.059	-0.216	-0.009	0.038	-0.030	0.058	0.058	0.007	-0.059	-0.281										
OTHER	0.009	0.015	-0.006	0.017	0.018	-0.100	-0.022	0.000	0.015	0.008	0.046	0.017	-0.007	-0.097	-0.123									
LSIZE	0.128	0.022	0.042	-0.108	-0.087	0.039	0.112	0.106	0.149	0.061	0.070	0.058	0.170	0.443	0.014	-0.006								
IND_1	-0.030	-0.030	0.035	0.086	-0.002	0.039	-0.122	0.106	-0.002	0.047	0.047	0.029	0.003	-0.034	0.008	0.001	-0.019							
IND_2	0.055	0.011	0.029	-0.041	0.067	0.096	0.290	0.048	-0.064	0.081	-0.041	0.082	-0.060	0.124	0.028	-0.035	-0.065	-0.274						
IND_3	-0.068	0.007	-0.110	-0.006	-0.026	-0.171	-0.136	-0.065	0.090	-0.032	0.006	-0.028	0.093	-0.081	-0.031	0.051	0.024	-0.225	-0.707					
DEBT_ CONST	-0.042	-0.110	-0.011	0.055	-0.001	0.004	-0.072	0.068	0.029	0.082	0.107	0.033	0.056	-0.003	0.055	-0.029	0.041	0.058	-0.160	0.145				
CRED_ COND	-0.025	-0.085	0.014	0.046	-0.004	-0.004	-0.054	0.051	0.023	0.062	0.095	0.042	0.091	0.011	0.035	-0.016	0.061	0.073	-0.155	0.162	0.898			
CRED_ LINE	-0.024	-0.095	-0.008	0.057	-0.002	-0.001	-0.079	0.035	0.031	0.089	0.107	0.031	0.049	0.015	0.029	-0.040	0.044	0.071	-0.127	0.117	0.913	0.812		
DEBT_ INFO	-0.062	-0.107	-0.036	0.042	0.002	0.015	-0.057	0.093	0.020	0.064	0.080	0.014	0.007	-0.034	0.081	-0.019	0.001	0.007	-0.138	0.102	0.811	0.544	0.582	
VC_ CONST	-0.010	-0.089	-0.042	0.037	-0.001	0.037	0.033	0.064	0.038	0.070	0.026	0.043	0.024	0.051	0.033	0.002	0.040	0.057	-0.068	0.058	0.530	0.477	0.455	0.459

Correlation matrix for cross-section 2006 (N=615)

	BREAK	MAIN	UNEMPLOY	LAGE	GENDER	QUAL	R&D	NP	MP	PCOMP	NPCOMP	LCAP	AG	GmbH	OTHER	LSIZE	IND_1	IND_2	IND_3	DEBT_ CONST	CRED_ COND	CRED_ LINE	DEBT_ INFO
MAIN	-0.028																						
UNEMPLOY	-0.033	0.062																					
LAGE	-0.064	0.040	0.078																				
GENDER	0.072	0.066	0.060	-0.032																			
QUAL	0.039	-0.021	-0.065	0.037	0.020																		
R&D	-0.061	-0.025	0.035	-0.124	0.008	0.091																	
NPCOMP	-0.043	-0.052	-0.009	0.015	0.012	0.037	0.250																
MP	-0.006	-0.020	0.010	0.004	0.003	0.005	0.248	0.058															
PCOMP	-0.008	0.048	0.002	-0.059	-0.024	0.052	-0.002	-0.019	-0.009														
NPCOMP	0.140	0.008	-0.050	-0.016	-0.035	0.056	0.036	0.077	0.155	0.032													
LCAP	0.009	0.087	-0.019	0.134	0.028	-0.017	0.043	-0.008	0.041	0.053	0.043												
AG	0.019	-0.029	-0.079	0.084	0.129	0.096	0.033	0.090	0.069	0.034	0.091	0.233											
GmbH	-0.090	-0.042	-0.074	-0.083	-0.228	0.001	0.078	-0.013	0.029	0.018	-0.042	-0.068	-0.270										
OTHER	0.004	-0.077	0.059	-0.006	-0.071	0.031	0.072	-0.027	0.080	-0.003	-0.048	-0.025	-0.064	-0.137									
LSIZE	0.051	-0.006	-0.099	-0.112	0.038	0.149	0.145	0.102	0.136	0.087	0.080	0.186	0.374	0.003	0.020								
IND_1	0.006	0.040	0.069	-0.008	0.062	-0.123	0.136	0.015	0.066	0.008	-0.057	0.060	-0.009	-0.004	-0.001	0.014							
IND_2	0.053	0.046	-0.033	0.039	0.082	0.331	0.072	-0.024	0.055	0.012	0.128	-0.090	0.118	0.035	-0.027	-0.043	-0.301						
IND_3	-0.056	-0.126	0.005	0.032	-0.182	-0.190	-0.091	0.071	-0.082	-0.047	-0.060	0.083	-0.076	-0.032	0.070	-0.018	-0.204	-0.694					
DEBT_ CONST	-0.176	0.014	0.110	-0.140	-0.020	-0.105	0.101	0.103	0.067	-0.008	0.009	-0.066	-0.093	0.109	0.014	0.039	0.048	-0.164	0.099				
CRED_ COND	-0.176	0.047	0.100	-0.103	-0.027	-0.132	0.073	0.074	0.069	0.049	-0.016	-0.026	-0.066	0.072	0.009	0.042	0.073	-0.194	0.113	0.920			
CRED_ LINE	-0.149	0.009	0.092	-0.122	-0.021	-0.111	0.091	0.089	0.041	-0.017	0.039	-0.061	-0.069	0.089	-0.004	0.031	0.065	-0.134	0.085	0.922	0.831		
DEBT_ INFO	-0.150	-0.020	0.106	-0.152	-0.005	-0.041	0.107	0.117	0.069	-0.053	0.001	-0.091	-0.117	0.134	0.034	0.031	-0.009	-0.113	0.069	0.855	0.652	0.655	
VC_ CONST	-0.087	-0.047	0.019	-0.071	-0.047	-0.061	0.090	0.148	0.068	0.036	0.026	-0.022	-0.027	0.075	0.010	0.040	-0.017	-0.087	0.080	0.561	0.513	0.487	0.513

C Appendix to Chapter 4

Table C.1: Descriptive statistics
(selection indicator included in the innovation models)

		Panel		Cross-sections						Test on statistical significant relationship between two cross-sections	
Period		1996/97-2006		1996/97-2000		2000-2003		2003-2006		2000 vs. 2003	2003 vs. 2006
Number of observations		2393		1204		707		482			
Variable	Type	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	p-value	p-value
IP	binary	0.478	0.500	0.502	0.500	0.451	0.498	0.456	0.499	0.030	0.859
R&D	binary	0.212	0.409	0.245	0.430	0.192	0.394	0.160	0.367	0.008	0.150
LEVEL_UNI	binary	0.232	0.422	0.233	0.423	0.235	0.424	0.224	0.417	0.911	0.666
LEVEL_O_TERTIARY	binary	0.468	0.499	0.459	0.499	0.472	0.500	0.483	0.500	0.579	0.710
TYPE_TECHNICAL	binary	0.211	0.408	0.205	0.404	0.214	0.410	0.224	0.417	0.661	0.667
TYPE_MANAGEMENT	binary	0.264	0.441	0.258	0.438	0.264	0.441	0.278	0.448	0.766	0.606
TYPE_MIX	binary	0.267	0.443	0.275	0.447	0.264	0.441	0.253	0.435	0.621	0.660
EXP_IND	binary	0.437	0.496	0.428	0.495	0.447	0.498	0.444	0.497	0.413	0.919
EXP_SELF	binary	0.101	0.301	0.107	0.309	0.098	0.297	0.089	0.285	0.508	0.627
EXP_RAD	binary	0.118	0.322	0.117	0.322	0.115	0.319	0.124	0.330	0.867	0.604
INNO_IDEA	binary	0.564	0.496	0.544	0.498	0.587	0.493	0.581	0.494	0.068	0.835
LAGE	continuous	3.649	0.234	3.650	0.237	3.652	0.231	3.644	0.231	0.860	0.585
MALE_TEAM	binary	0.672	0.470	0.681	0.466	0.663	0.473	0.662	0.474	0.425	0.956
MIXED_TEAM	binary	0.232	0.422	0.222	0.416	0.238	0.426	0.247	0.432	0.425	0.714
TEAM_FOUNDATION	binary	0.473	0.499	0.478	0.500	0.471	0.500	0.465	0.499	0.754	0.831
LSIZE	continuous	0.485	0.734	0.347	0.584	0.565	0.790	0.710	0.895	0.000	0.003
EXPORT	binary	0.247	0.432	0.263	0.441	0.231	0.421	0.232	0.423	0.111	0.942
DIVERSIFICATION	binary	0.496	0.500	0.503	0.500	0.494	0.500	0.479	0.500	0.683	0.626
DEMAND_FUTURE	binary	0.585	0.493	0.762	0.426	0.342	0.475	0.498	0.501	0.000	0.000
COOPERATION	binary	0.393	0.488	0.433	0.496	0.335	0.472	0.378	0.485	0.000	0.133
PCOMP	binary	0.461	0.499	0.422	0.494	0.506	0.500	0.494	0.500	0.000	0.670
NPCOMP	binary	0.533	0.499	0.543	0.498	0.528	0.500	0.515	0.500	0.509	0.658
MANUFACT	binary	0.077	0.267	0.080	0.271	0.075	0.264	0.075	0.263	0.707	0.986
MOD_SERV	binary	0.467	0.499	0.456	0.498	0.460	0.499	0.504	0.501	0.875	0.132
TRAD_SERV	binary	0.365	0.482	0.373	0.484	0.379	0.485	0.326	0.469	0.789	0.060
Y2003	binary	0.295	0.456								
Y2006	binary	0.201	0.401								

Notes: To test the relationship for binary variables, we used Pearson's chi-squared (H_0: the rows and columns in a two-way table are independent). Test results for continuous variables are based on two independent sample t-tests (H_0: variable has the same mean within the two cross-sections).

Table C.2: Test for selective attrition (selection indicator included in the innovation models)

Dependent variable	IP				R&D			
Period	1996/97-2000	1996/97-2000	2000-2003	1996/97-2003	1996/97-2000	1996/97-2000	2000-2003	1996/97-2003
Founder characteristics								
LEVEL_UNI	0.272**	0.271**	0.321**	0.311***	0.588***	0.590***	0.383**	0.496***
	(0.115)	(0.116)	(0.151)	(0.091)	(0.139)	(0.138)	(0.177)	(0.108)
LEVEL_O_TERTIARY	0.061	0.062	0.131	0.108	0.333***	0.336***	-0.058	0.199**
	(0.093)	(0.093)	(0.122)	(0.073)	(0.120)	(0.119)	(0.154)	(0.094)
TYPE_TECHNICAL	0.169	0.170	0.010	0.108	0.439***	0.439***	0.442**	0.413***
	(0.121)	(0.121)	(0.157)	(0.095)	(0.142)	(0.142)	(0.182)	(0.112)
TYPE_MANAGEMENT	0.047	0.048	-0.022	0.031	-0.188	-0.192	-0.398*	-0.271**
	(0.111)	(0.111)	(0.144)	(0.088)	(0.146)	(0.147)	(0.216)	(0.120)
TYPE_MIX	0.225**	0.222**	-0.010	0.145*	0.277**	0.274**	0.078	0.194*
	(0.112)	(0.112)	(0.146)	(0.088)	(0.137)	(0.137)	(0.186)	(0.110)
EXP_IND	-0.061	-0.061	-0.002	-0.060	-0.147	-0.143	-0.178	-0.171**
	(0.084)	(0.084)	(0.109)	(0.066)	(0.103)	(0.103)	(0.137)	(0.082)
EXP_SELF	0.213	0.211	-0.082	0.087	0.342**	0.341**	0.083	0.260**
	(0.135)	(0.135)	(0.181)	(0.106)	(0.157)	(0.156)	(0.214)	(0.125)
EXP_RAD	0.650***	0.650***	0.432**	0.529***	1.162***	1.161***	0.976***	1.033***
	(0.149)	(0.149)	(0.175)	(0.112)	(0.144)	(0.144)	(0.179)	(0.110)
INNO_IDEA	0.325***	0.327***	0.119	0.220***	0.489***	0.494***	0.306**	0.421***
	(0.081)	(0.081)	(0.108)	(0.064)	(0.101)	(0.101)	(0.146)	(0.081)
LAGE	-0.037	-0.038	-0.442*	-0.200	0.233	0.237	-0.133	0.036
	(0.170)	(0.170)	(0.226)	(0.134)	(0.209)	(0.208)	(0.292)	(0.168)
MALE_TEAM	-0.063	-0.062	0.055	-0.023	0.370*	0.371*	0.093	0.284*
	(0.145)	(0.145)	(0.184)	(0.112)	(0.210)	(0.211)	(0.253)	(0.162)
MIXED_TEAM	-0.055	-0.049	-0.091	-0.062	0.234	0.237	-0.227	0.078
	(0.176)	(0.177)	(0.225)	(0.136)	(0.236)	(0.236)	(0.318)	(0.187)
TEAM_FOUNDATION	0.060	0.056	0.272**	0.137*	-0.083	-0.084	0.122	-0.007
	(0.104)	(0.105)	(0.138)	(0.083)	(0.123)	(0.123)	(0.168)	(0.099)
Firm characteristics								
LSIZE	0.130	0.131	0.024	0.048	-0.021	-0.020	0.032	-0.005
	(0.109)	(0.109)	(0.102)	(0.050)	(0.123)	(0.123)	(0.126)	(0.061)
EXPORT	0.337***	0.338***	0.488***	0.363***	0.414***	0.414***	0.188	0.342***
	(0.096)	(0.096)	(0.125)	(0.075)	(0.101)	(0.101)	(0.145)	(0.080)
DIVERSIFICATION	0.449***	0.446***	0.174*	0.318***	0.202**	0.204**	0.106	0.152**
	(0.079)	(0.079)	(0.103)	(0.062)	(0.096)	(0.096)	(0.132)	(0.077)
Market conditions								
DEMAND_FUTURE	0.367***	0.370***	0.234**	0.316***	0.205*	0.207*	0.089	0.153*
	(0.093)	(0.093)	(0.107)	(0.070)	(0.118)	(0.118)	(0.134)	(0.088)
COOPERATION	0.384***	0.384***	0.292***	0.352***	0.724***	0.725***	0.765***	0.684***
	(0.082)	(0.082)	(0.109)	(0.065)	(0.098)	(0.098)	(0.132)	(0.076)
PCOMP	-0.066	-0.065	-0.003	-0.051	-0.155	-0.156	0.001	-0.101
	(0.080)	(0.080)	(0.101)	(0.062)	(0.096)	(0.096)	(0.128)	(0.075)
NPCOMP	0.341***	0.343***	0.180*	0.264***	0.047	0.043	0.259**	0.133*
	(0.080)	(0.080)	(0.103)	(0.062)	(0.098)	(0.098)	(0.131)	(0.077)
MANUFACT	-0.012	-0.016	0.705***	0.260*	1.009***	1.012***	0.770**	0.982***
	(0.194)	(0.194)	(0.268)	(0.155)	(0.267)	(0.267)	(0.329)	(0.207)
MOD_SERV	-0.005	-0.005	0.500**	0.173	0.768***	0.772***	0.333	0.639***
	(0.152)	(0.151)	(0.210)	(0.120)	(0.234)	(0.233)	(0.279)	(0.179)
TRAD_SERV	0.106	0.102	0.585***	0.277**	0.640***	0.649***	0.331	0.577***
	(0.150)	(0.150)	(0.207)	(0.119)	(0.235)	(0.234)	(0.274)	(0.179)
Y2003				0.017				-0.076
				(0.071)				(0.090)
INSAMPLE_03	-0.007				0.095			
	(0.080)				(0.099)			
INSAMPLE_06		-0.051	0.056			0.051	-0.320**	
		(0.082)	(0.110)			(0.096)	(0.132)	
INSAMPLE_NEXT_PERIOD				0.136				-0.038
				(0.090)				(0.107)
CONSTANT	-1.345**	-1.326**	0.061	-0.749	-4.203***	-4.193***	-1.670	-2.984***
	(0.663)	(0.664)	(0.877)	(0.520)	(0.846)	(0.845)	(1.132)	(0.671)
N	1186	1186	702	1894	1186	1186	702	1894
Pseudo R^2	0.156	0.157	0.113	0.127	0.314	0.313	0.269	0.281
Wald chi^2	220.53***	220.91***	105.18***	300.71***	301.97***	300.22***	162.76***	442.34***

Notes: See Table 4.1 for the variable definitions; heteroskedasticity-robust standard errors (White procedure) are in brackets under the coefficients; ***, **, * denotes statistical significance at the 1%, 5% and 10% test level, respectively.

Table C.3: Correlation matrix (N=2393)

	LEVEL_UNI	LEVEL_O_TERTIARY	TYPE_TECHNICAL	TYPE_MANAGEMENT	TYPE_MIX	EXP_IND	EXP_SELF	EXP_RAD	INNO_IDEA
LEVEL_O_TERTIARY	-0.515								
TYPE_TECHNICAL	0.077	0.011							
TYPE_MANAGEMENT	-0.014	0.076	-0.310						
TYPE_MIX	-0.023	0.029	-0.313	-0.362					
EXP_IND	-0.034	0.054	-0.060	0.010	0.146				
EXP_SELF	0.063	-0.025	-0.024	0.030	-0.058	-0.222			
EXP_RAD	0.131	-0.008	0.236	-0.143	0.081	-0.165	-0.092		
INNO_IDEA	0.099	0.000	0.049	0.001	0.141	0.079	-0.025	0.089	
LAGE	0.067	0.037	-0.108	0.144	-0.008	-0.016	0.104	0.054	-0.071
MALE_TEAM	-0.013	-0.005	0.085	-0.056	-0.004	-0.036	-0.041	0.021	-0.020
MIXED_TEAM	0.042	0.011	-0.015	-0.005	0.020	0.034	0.093	0.021	-0.013
TEAM_FOUNDATION	0.138	-0.063	0.028	-0.082	0.038	0.046	0.186	0.095	0.030
LSIZE	0.059	-0.032	0.017	-0.059	0.036	0.057	0.039	0.022	0.045
EXPORT	0.161	-0.039	0.045	-0.025	0.072	-0.017	0.024	0.190	0.102
DIVERSIFICATION	-0.009	0.022	-0.055	0.007	0.102	-0.013	-0.012	0.016	0.054
DEMAND_FUTURE	0.040	-0.023	-0.035	0.005	0.050	0.034	-0.028	0.027	0.073
COOPERATION	0.084	-0.009	0.086	-0.068	0.046	-0.016	-0.016	0.115	0.105
PCOMP	-0.011	0.014	0.007	0.008	0.051	0.022	-0.065	0.026	0.063
NPCOMP	0.045	0.009	-0.009	0.020	0.074	0.004	-0.035	0.062	0.072

	LAGE	MALE_TEAM	MIXED_TEAM	TEAM_FOUNDATION	LSIZE	EXPORT	DIVERSIFICATION
MALE_TEAM	-0.019						
MIXED_TEAM	0.030	-0.786					
TEAM_FOUNDATION	-0.057	-0.405	0.567				
LSIZE	-0.039	-0.005	0.065	0.320			
EXPORT	0.082	0.029	0.009	0.062	0.069		
DIVERSIFICATION	-0.026	0.029	0.044	0.026	0.074	0.104	
DEMAND_FUTURE	-0.061	0.013	0.022	0.061	0.010	0.073	0.093
COOPERATION	-0.046	0.041	0.039	0.098	0.042	0.177	0.154
PCOMP	-0.045	-0.039	0.059	0.079	0.046	-0.016	0.028
NPCOMP	-0.014	-0.005	0.047	0.043	0.043	0.056	0.040

	DEMAND_FUTURE	COOPERATION	PCOMP
COOPERATION	0.110		
PCOMP	-0.067	0.047	
NPCOMP	0.125	0.110	0.065

Curriculum Vitae

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